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ORIGINAL ARTICLES.

I.—*Lophophyllum* and *Cyathaxonia*: Revision Notes on two genera of Carboniferous Corals.[1]

By R. G. Carruthers, F.G.S.

(PLATE III.)

THREE years ago when I was discussing certain Carboniferous Corals from Arctic regions the opinion was expressed that the genus *Lophophyllum* of Milne-Edwards & Haime had been erroneously interpreted by palæontologists, and that in reality it included Thomson and Nicholson's well-known genus *Koninckophyllum*.[2] The main object of the present communication is to substantiate this view with illustrative sections from topotypes, accompanied by some further observations on the genus. At the same time the opportunity is taken to deal with several points in the morphology of the similar genus *Cyathaxonia*; in the latter case the work is in the nature of a preliminary note rather than of a formal revision. Pending the appearance of a general memoir on the British Carboniferous Corals, it seems desirable that these notes should be published without further delay, as all these genera are commonly met with in zonal work. Most of the material has come either from the Geological Survey Collection or is in my own possession, but Dr. Vaughan has always been very helpful, while I have to thank Dr. T. F. Sibly for some unusually fine examples of *Cyathaxonia* from Matlock. Other specimens of this genus, from Yorkshire, have very kindly been sent to me from time to time by Dr. A. Wilmore, often at some personal inconvenience.

LOPHOPHYLLUM. (Pl. III, Figs. 1, 2, 3.)

The genus *Lophophyllum* was founded by Milne-Edwards & Jules Haime in 1850, when they published a description and figures of the genotype, *L. koninckı*, in their monograph *Les Polypes Fossiles des Terrains Paléozoiques*.[3] The figured specimen was sent to them by de Koninck from Tournai, and is now apparently lost, since it could not be found amongst other figured material of theirs examined by the writer in 1907 at the Musée d'Histoire Naturelle, Paris.

[1] Communicated by permission of the Director of the Geological Survey of Great Britain.

[2] "A Carboniferous Fauna from Nowaja Zemlja," by G. W. Lee, D.Sc., with notes on the Corals by R. G. Carruthers: Trans. Roy. Soc. Edin., vol. xlvii, pt. i (No. 7), p. 152, 1909.

[3] Loc. cit., p. 349, pl. iii, figs. 4, 4*a*.

In 1846, four years previous to the publication of the *Polypes Fossiles*, a similar coral had been figured and described by Michelin[1] under the designation *Cyathaxonia tortuosa*; his type also came from Tournai, but seems to be missing from the remnants of his collection, now stored in the Musée d'Histoire Naturelle. It may be remarked in passing that in other cases where the original specimens were available for comparison, Michelin's figures proved to be tolerably accurate, while those given by Milne-Edwards & Haime are remarkably faithful.

The work of both Michelin and of Milne-Edwards & Haime clearly shows that they were dealing with a coral which had a smooth epitheca and a prominent columella; in the absence of the holotypes, these characters are of great importance in recognizing their 'species'.

The general constitution of the Tournai fauna is well known, and the corals in particular have been exhaustively dealt with by de Koninck. From the published accounts, confirmed by a personal examination of four large collections and of many quarries round Tournai, it can be stated confidently that in this peculiar fauna there are only two coral species with a strong columella. One of these is Michelin's *Cyathaxonia cornu*, but as this is relatively very small, and has strong longitudinal ribbing on the epitheca, it is clearly not to be confounded with either *C. tortuosa* or *Lophophyllum koninckı*. The remaining form agrees with the figures and descriptions of both of the last-named 'species', and it is therefore concluded that these are synonymous. Generically, the first of these corals is not a true *Cyathaxonia*, as it develops dissepiments in the mature growth-stages. Michelin's specific name can be retained, however, as it has considerable priority. The genotype of *Lophophyllum* is accordingly taken to be *L. tortuosum*, and a diagnosis is appended below.

LOPHOPHYLLUM TORTUOSUM (Mich.). (Pl. III, Figs. 1, 2.)

The chief references are—

1846. *Cyathaxonia tortuosa*, Michelin, *Iconographie Zoophytologique*, p. 258, pl. lix, fig. 8.

1850. *Lophophyllum koninckı*, Milne-Edwards & Jules Haime, *Polypes Fossiles des Terrains Paléozoiques*, p. 349, pl. iii, figs. 4, 4*a*.

External Characters.

Corallum (see Pl. III, Figs. 1, 1*a*, 2).—Simple, cornute, frequently showing short root-like processes of attachment at the base. *Epitheca* thin, smooth, with fine annular striations, and a few constrictions of growth; traces of longitudinal ribbing very faint or absent entirely. *Calyx* deep. *Major septa* thin and reaching to the columella, which forms a long lath-like projection in the centre of the calyx. *Minor septa* well developed, thin; *dissepiments* appear round the inside of the calicinal wall, but are not a prominent feature. The *cardinal fossula* is deep, and lies on the convex side of curvature of the corallum.

[1] Michelin, *Iconographie Zoophytologique*, p. 258, pl. lix, fig. 8.

Internal Characters.

Transverse Sections (Pl. III, Figs. 1*b–e*).—All the septa extend to the epitheca throughout the coral, while in the younger growth stages there are no dissepiments, although these appear later on, in a narrow ring next to the epitheca (Pl. III, Figs. 1*d–e*). The major septa extend to the thin lath-like columella (which is a direct continuation of the counter septum) until the final growth-stages; they then become amplexoid and fall away, leaving a bare tabular area in the centre of the coral. Through this bare central area the columella continues to project, surrounded by thin wavy lines, representing the edges of upraised tabulæ cut off by the plane of sections (Pl. III, Fig. 1*e*). At this stage the columella is often fringed with small projections, which are the remnants of attached septa; their length varies according to the proximity of the section to a tabula, the septa being always most fully developed on the upper surface of a tabula.[1] The large cardinal fossula is especially prominent in the younger growth-stages, when it is expanded inwardly and completely enclosed by the major septa (Pl. III, Figs. 1*b–c*).

Vertical Sections (Pl. III, Fig. 1*f*).—The tabulæ rise steadily up to the columella, but there is no central zone in which they are closer and more sharply elevated, as in other Clisiophyllids (*Dibunophyllum*, etc.).

The columella is continuous throughout, while the dissepiments are small, forming a narrow outer ring of two or three rows only.

Distribution.

The opportunity is here taken to discuss the horizon and fauna of the Carboniferous Limestone around Tournai, from which so many corals, including those now under consideration, were originally described.

De Koninck and his predecessors simply gave 'Tournai' as the locality for many of their fossils. The district[2] has for long been a favourite hunting-ground with collectors, on account of the remarkably perfect condition of the fossils; they are silicified, and can be picked out of a soft matrix in the vertical fissures of decalcified limestone which traverse the quarries. There are scores of quarries around Tournai, and the fauna is rich and varied. At first sight, therefore, the mere word 'Tournai' would seem to be insufficient as a locality index, more especially as a list of forms so recorded shows a mixture of species which are zones apart in most British areas (e.g. the South-Western Province). Nevertheless, actual inspection of the ground shows that this intermixture is a fact. Additional proof is thereby accorded to the contention (readily admitted by Dr. Vaughan) that the English 'zones' are in some degree based on a non-genetic sequence of faunas determined by a given set of

[1] A parallel instance has been fully described and illustrated in *Caninia cornucopiæ*, see this Magazine, Dec. V, Vol. V, p. 165, Diagram F, 1908.

[2] The Tournai region has been treated in detail in a valuable and comprehensive stratigraphical study of the Lower Carboniferous rocks of Belgium and their relationship to British areas. See M. Delépine, *Recherches sur le Calcaire Carbonifère de la Belgique*, pp. 214–41, Lille, 1911.

physical conditions, and accordingly liable to considerable lateral change and variation.

I have lately had an opportunity to see part of the Belgian sequence under the guidance of M. Delépine. The limestones round Tournai are remarkably flat, so that the numerous large quarries are practically all on the same horizon, ascribed by M. Delépine to the C or Upper Tournaisian sub-zone of Dr. Vaughan's scheme. The assemblage of corals in the quarries visited (Baguette, Pont-a-Rieux, Vaulx, Allain, etc.) was much the same throughout; a typical list from Pont-a-Rieux gives, in order of abundance: *Caninia cornucopiæ*, *Cyathaxonia cornu*, *Zaphrentis omaliusi*, *Z. densa*, *Amplexus spinosus*, *Caninia patula*, *Zaphrentis koninckı*, *Z. delanouei*, *Lophophyllum tortuosum*, and *Syringothyris* sp. There were also two species of *Michelinia* and some '*Paleacis*'-like forms, not yet fully identified. *Caninia cylindrica* was not noticed here; M. Delépine has found it at a slightly higher horizon at other quarries in the district.

I also noticed several specimens of *Lophophyllum tortuosum* in the Calcaire de Landelies, along the banks of the Sambre; the level here is given by M. Delépine as Z_2, and is accordingly slightly lower than at Tournai. In Dr. Vaughan's collection from the Bristol district there is an isolated example of this species from the Z_2 sub-zone, and in the Geological Survey Collection there is another specimen from this level in South Wales (Pr. 2933). I have recognized another example collected by Mr. John Smith, of Dalry, from the Lower Limestone of Castletown in the Isle of Man.[1] This specimen (quite normal, except that the dissepiments begin earlier) is of unusual interest, because the horizon seems to be well up in the Visean, and indeed has been considered by Dr. Wheelton Hind to belong to the D_2 sub-zone.[2] Otherwise *L. tortuosum* appears to be a characteristically Tournaisian species.

Remarks.

Lophophyllum tortuosum must certainly be grouped with those corals referred to *Koninckophyllum* at the present time. But the latter genus was founded by Thomson & Nicholson in 1876,[3] long subsequent to *Lophophyllum*, which these authors (relying on the original diagnosis, instead of the re-examination of topotypes) regarded as a Zaphrentid coral with one of the major septa prolonged and thickened. This conception has been followed by other writers, especially in America.

The *Koninckophylla* are occasionally compound, but it does not seem possible to separate such forms generically; the few that are characteristically compound (e.g. *Koninckophyllum proliferum*) can sometimes be found as 'simple', or isolated, coralla, and in all other respects their differences from *Lophophyllum tortuosum* are merely specific. I would suggest, therefore, that the genus *Koninckophyllum* of Thomson & Nicholson, and also those corals referred by Thomson to

[1] Trans. Geol. Soc. Glasgow, vol. xiv, pt. ii, p. 151, 1911. In the lists appended to this paper most of the corals have been named by Mr. Smith himself.

[2] Proc. Yorks Geol. Soc., vol. xvi, pt. ii, p. 150, 1907.

[3] Ann. Mag. Nat. Hist., vol. i, p. 297, 1876.

Acrophyllum,[1] should be abandoned, on the score of priority, in favour of *Lophophyllum*, of which an amended diagnosis may be given as follows:

Corallum simple and turbinate. Major septa meeting in the centre of the coral in the early growth-stages. One of the septa, usually the counter septum, is strongly thickened at the inner end, giving rise to a prominent *columella*, which may be discontinuous. In the more mature growth-stages the columella persists, but the septa usually retreat from the centre and become amplexoid, while dissepiments appear between the tabulæ and the wall. The tabulæ are arched upwards in the centre to a varying degree, but, unlike such genera as *Dibunophyllum*, there is no central zone where the tabulæ are more numerous or vesicular, nor is there a system of vertical lamellæ distinct from the septa.

Those corals referred by Nicholson & Thomson and other authors to *Lophophyllum* (e.g. *L. proliferum* and *L. eruca*) do not develop dissepiments at any stage of growth, and are essentially *Zaphrentes* having one of the septa thickened at the inner end. It may be convenient at some future time to group them as a sub-genus of *Zaphrentis*, but for the present such a course is not considered advisable.

Notes on the Lophophylloid columella.—The columella of a *Lophophyllum* is not, as in *Cyathaxonia*, a structure independent of the septa; on the contrary, it is simply a direct continuation of one or more of the major septa (usually the counter septum, sometimes of the cardinal or other major septa in addition). This fact is brought out on examining a thin vertical section, cut as nearly as possible down the centre line of the counter septum. Such a section is shown on Pl. III, Fig. 3, the subject being a '*Koninckophyllum*' from the Scottish Lower Limestone Group (approximately of D_2 age). In this section the fine radiating striæ represent the crystalline fibres of the skeleton; these spring from dark points, which are arranged in ill-defined linear series, one for each layer of growth. When these lines are followed inwards from the outer end of the septum (right-hand side of figure) they are seen to curve downwards and then gradually rise towards the centre of the coral, where they have a dome-like arrangement (the 'columella'). It is accordingly clear that there was continuous deposition of material along the upper edges of both septum and 'columella', and that the latter is, essentially, a mere continuation of the septum. The case is different in *Cyathaxonia*, as will presently be shown.

Genus CYATHAXONIA, Mich. (Pl. III, Figs. 4–10.)

The genotype of *Cyathaxonia* may be taken as *C. cornu*[2]; as in the preceding case, the type-specimen is lost, but the original figures

[1] Thomson was mistaken in his conception of this genus, which was distinctly stated by Nicholson to have no columella. Good figures of the genotype, *A. oneidense* (Billings), are given by Lambe in *Contrib. to Canadian Pal.*, vol. iv, pt. i, pl. xvi, figs. 1, 2, 1899.

[2] No genotype was given by Michelin; Milne-Edwards and Haime selected *C. cornu*, and their example is here followed, for reasons which will be explained in detail elsewhere. This course does no injustice to Michelin: whereas a rigid interpretation of the law would necessitate a radical change in the long-established conception of *Cyathaxonia*, and this for purely academic reasons.

and description amply suffice, there being no risk of confusion with any other Tournai fossil.

Tabulæ.—Apparently it has always been supposed that this beautiful little coral had no tabulæ, being open from top to bottom. Chiefly on this ground the genus has been placed in a family apart from other Palæozoic corals (the Cyathaxonidæ of Milne-Edwards & Haime), which has supplied material for much ingenious speculation as to possible descendants amongst the Hexacoralla. As a matter of fact, tabulæ are present in abundance; they are, however, very thin, and doubtless the misconception arose because these little fossils, as found at Tournai, are invariably silicified, and so fragile that tabulæ are not apparent on breaking open a specimen. But if the coral be first steeped in hot Canada balsam, and then carefully ground down, a thin section can be made, in which the tabulæ are clearly seen, rising upwards to the strong central columella (Pl. III, Fig. 6). When the specimens are calcareous, as are most of those from British and Irish localities, vertical sections showing tabulæ are readily obtained, although microscopical examination is generally requisite, owing to the very small size of this species.

Columella.—At the extreme tip of the corallum no trace of a columella can be seen, the septa simply meeting at the centre.[1] When eight or nine septa have developed (the number varies considerably) the columella appears, and quickly attains prominence.

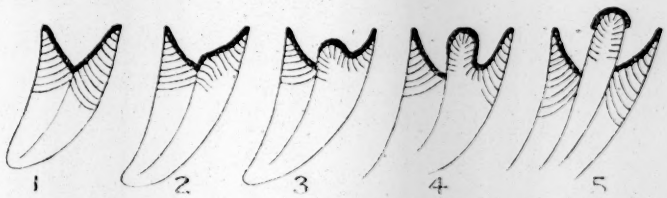
Both vertical and transverse sections show that the columella is, structurally, quite independent of the septa. Thin transverse sections (Pl. III, Fig. 4) show the calcite fibres radiating outwards from a central point, usually dark; concentric coloured growth-rings are usually to be seen round this axis. The major septa are fused against the columella, but in no way partake in its construction, for their crystalline fibres and central dark or white line terminate as soon as the columella is reached (Fig. 4, Pl. III, is too small to illustrate this point, which is better seen in the section of *C. rushiana*, Fig. 10).

Vertical sections also demonstrate the independence of the columella and septa. The section shown in Fig. 5, Pl. III, is cut down the axial plane of the coral, along the centre of both the columella and of the major septum on each side. Here, again, the arrangement of the crystalline fibres (at right angles to which growth takes place) indicates the absolute lack of continuity between septa and columella, although these latter are in complete contact.

Compared with *Lophophyllum*, the columella of a *Cyathaxonia* may be regarded as an extreme case of the upward bending of a septum in the centre of a coral, developed to such a degree that severance has taken place and an independent structure arisen. This conception is here illustrated in diagram form, figures of two other forms being added to show progressive divergence from a typical *Zaphrentis*, although a phylogenetic connexion is by no means implied.

[1] The primary septation of *Cyathaxonia cornu* forms the basis of a paper by M. Faurot ("Affinités des Tétracoralliaires et des Hexacoralliaires": *Annales de Paléontologie*, tom. iv, 1909). This important communication deserves separate treatment, and is therefore only referred to here.

The tabulæ of *Cyathaxonia* do not contribute in any way towards the construction of the columella; they remain uniformly thin right up to their connexion with the latter, and never show any trace of passage into that structure. The columella of *Cyathaxonia* is therefore developed at a very early stage, and it is built up round an imaginary central axis, remaining throughout quite independent of septa or tabulæ, although these are in complete contact with it. In Dr. Vaughan's species, *C. rushiana*, the columella is relatively larger than in *C. cornu*, and in transverse sections shows a marked elongation in line with the cardinal fossula. This is occasioned by the radiation of the crystalline fibres from an imaginary l i n e instead of a p o i n t; this 'line' is usually either darker or lighter than the rest of the columella, although occasionally no colour differentiation can be seen. With the exception that most specimens are three or four times larger than *C. cornu*, there is no further difference between the two species, and all gradations can be found between them.



Diagrammatic representation of vertical sections cut down septa, in the cardinal-counter septal plane, illustrating the formation of the columella in *Lophophyllum* and *Cyathaxonia*. Thick lines indicate growth region; thin lines, direction of crystalline fibres.

FIG. 1. *Zaphrentis omaliusi.*
,, 2. *Zaphrentis eruca* (*Lophophyllum* auctt.).
,, 3.) *Lophophyllum* (*Koninckophyllum* auctt.).
,, 4.)
,, 5. *Cyathaxonia cornu.*

Septa.—Both *C. cornu* and *C. rushiana* have very long minor septa, which appear at a very early period, when perhaps only seven or eight major septa have developed. These minor septa all lean inwards away from the cardinal fossula, and each one ultimately fuses with a major septum; the pair in the counter fossula (one on each side of the counter septum) are longer than the rest (Pl. III, Figs. 4, 9, and 10) and invariably appear first, sometimes before the conclusion of the protoseptal stage, with six primary septa. They are not formed by a splitting of the major septa, but are minor septa in the strict morphological sense, as is shown by their development and by their relation to the vertical furrows on the epitheca. On examining a good specimen it will be noticed that each alternate furrow coincides with one of the longer series of septa, and each furrow between corresponds to one of the shorter series. The latter are therefore the minor septa, this rule holding good in all Rugose corals. The remarkable length of the minor septa, and their general disposition, frequently aid in the recognition of these two species, especially when silicification has obscured the columella.

Carinæ.—There is another peculiarity which can often be noticed in either species. In transverse sections little jagged projections may be visible along the edges of the septa (see Pl. III, Fig. 9). In a vertical section cut parallel to, but not quite touching, the face of the septa these projections are seen to be spines, which are arranged in linear series parallel to the free edges of the septa (Pl. III, Fig. 8). They are, in fact, *carinæ*, such as are common enough in Devonian corals. The appearance of this phenomenon in Carboniferous times is somewhat of a mystery, for these structures do not seem to occur in Tournaisian specimens of *Cyathaxonia*, while they are often met with in strata of Visean age. Curiously enough, the only other Carboniferous coral where this feature seems to have been noticed (a new species of *Campophyllum*[1]) also comes from Visean beds. Septal projections in *Cyathaxonia* were first recorded by Dr. A. Vaughan.[2] He considered that they might be the remnants of tabulæ subsequently destroyed, a not unnatural view in the absence of vertical sections to demonstrate their true nature. As previously mentioned, carinæ have been observed in both *C. cornu* and *C. rushiana*. They are not traceable in examples of *C. cornu* from Tournai, and cannot be considered of diagnostic value in either species.

EXPLANATION OF PLATE III.

Photographed from camera lucida drawings (except Figs. 1, 1*a*, and 2).

FIG. Figs. 1–2, *Lophophyllum tortuosum* (Mich.).

1. Profile view. Nat. size. Cornet Quarry, Tournai.
1*a*. Calyx of above specimen. Nat. size.
1*b–e*. Serial transverse sections from above specimen. Nat. size.
1*f*. Vertical section from middle portion of above. Nat. size.
2. Another specimen. Side view with part of calyx broken away, showing the columella. Nat. size.
3. *Lophophyllum* sp. (*Koninckophyllum* auctt.). Vertical section. × 3. Petershill Quarry, Bathgate.

Figs. 4–7, *Cyathaxonia cornu*, Mich.

4. Central part of transverse section. × 8. Southford Quarry, Dunfermline.
5. Part of median vertical section down septa and columella. × 8. Southford Quarry, Dunfermline.
6. Vertical section, showing the tabulæ. × 2. Cornet Quarry, Tournai.
7. Transverse section. × 2. Cornet Quarry, Tournai.
8. Vertical section, showing tabulæ and carinæ. × 5. Stock, near Bracewell.
9. Transverse section from above, showing carinæ. × 5.
10. *Cyathaxonia rushiana*, Vaughan. Central part of transverse section. × 8. Bradbourne, Derbyshire.

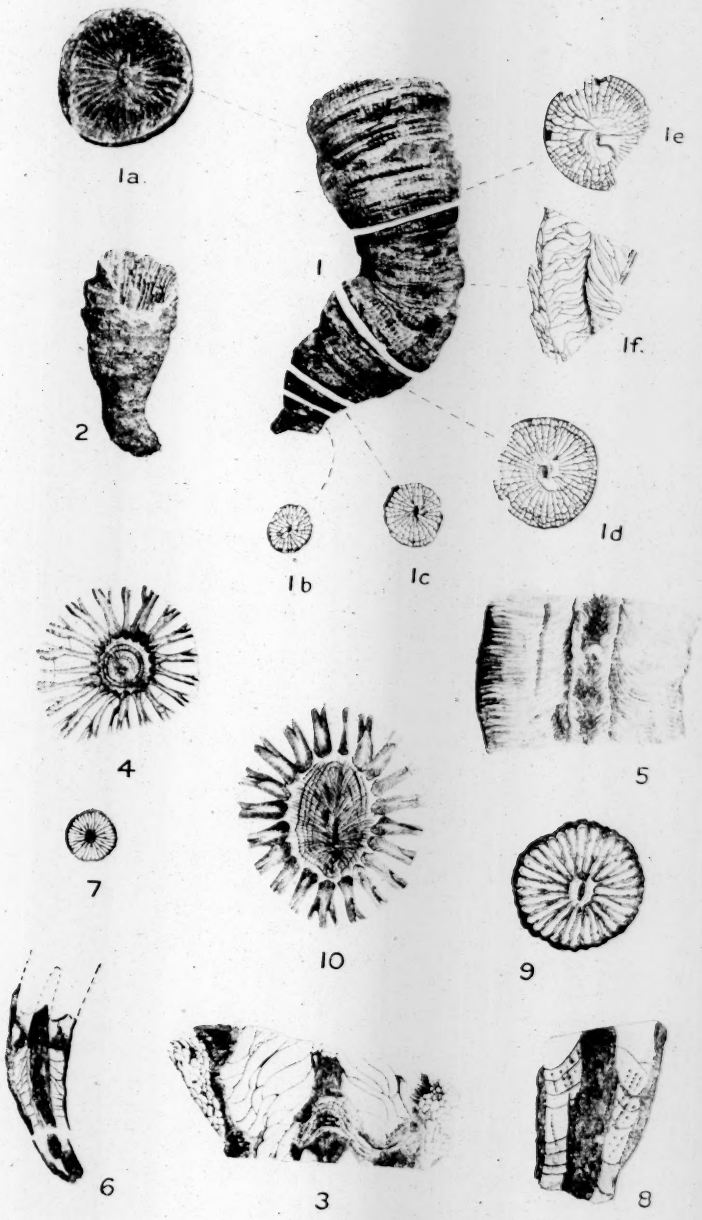
II.—The proposed Recognition of Two Stages in the Upper Chalk.

By R. M. Brydone, F.G.S.

IN the Geological Magazine for July and August last Mr. A. J. Jukes-Browne made a proposal for the recognition in England, France, and Germany of a boundary-line between two corresponding

[1] Lee & Carruthers, loc. cit., p. 150, pl. i, figs. 3–6.

[2] "The Carboniferous Succession at Loughshinny": Q.J.G.S., vol. lxiv, p. 460, 1908.



R. G. Carruthers photo.

Lophophyllum and *Cyathaxonia*.

stages in the middle of the old zone of *Actinocamax quadratus*. The reception to be given to this proposal so far as it concerns France and Germany must be a matter for the geologists of those countries, and I am concerning myself chiefly with the proposal as it affects the English Chalk. Inasmuch as I sympathize with the proposal, and my own work is partly relied upon, it may seem ungracious in me to criticize it, but there are several points on which criticism seems desirable if only to afford Mr. Jukes-Browne an opportunity of replying while the subject is still fresh.

In the first place, he appears to intend at the top of p. 306 to endorse a proposal by me to constitute a new zone, the zone of *Offaster pilula*, for the reception of the lower two out of the three subzones into which Mr. Griffith and I divided the old zone of *A. quadratus*. It is, however, not very clear that this is so, and any uncertainty is rather unfortunate, as when he wrote my proposal was still unpublished, being taken by him from letters in which I told him that I was about to publish such a proposal and gave my main new grounds in order to obtain his opinion as to the permissibility of a subsidiary proposal. It was, perhaps, inevitable if he could not wait for the publication of my proposal—now happily accomplished[1]—that he should quote from these letters; but it seems hardly fair that in doing so he should ignore the new grounds on which the proposal was based, or that he should write on p. 369 that the line at the top of the zone of *O. pilula* had not yet been accurately determined in England when the letters from which he apparently drew the main proposal of a zone of *O. pilula* in England showed that this line *had* been accurately determined in South England, to which my proposal was limited.

In the second place, in his list of zones on p. 308 the zone above that of *Marsupites* appears as the "zone of *Offaster pilula*". At the foot of p. 310 it appears without warning as the "zone of *Actinocamax granulatus*". In Table II it appears again without warning as the "zone of *Offaster pilula* and *Actinocamax granulatus*". In Table III it again changes to "zone of *Offaster pilula*", in Tables V and VI to "zone of *Offaster pilula* and *Actinocamax granulatus*", in Table VII to "zone of *Offaster pilula*", and finally in Table IX to "zone of *Offaster pilula* and *Actinocamax granulatus*". These apparently arbitrary intrusions of *A. granulatus*, when read with the statement next but one to be criticized, leave me practically certain that Mr. Jukes-Browne intended, at any rate during part of the time he was writing, to lay it down that the ranges of *A. granulatus* (upwards from the *Marsupites* zone) and *A. quadratus* (below the *Belemnitella mucronata* zone) corresponded with the two divisions of the old zone of *A. quadratus* on which he was working.

I am afraid that on this point he may have fallen into a trap which I certainly laid for him, though quite unwittingly. In "The Zones of the Chalk in Hants", *A. granulatus* appears as having occurred in four of the collated pits in the *subzone* of *O. pilula* (which is the upper part of the new *zone* of *O. pilula*). All the specimens in question

[1] See *The Stratigraphy of the Chalk of Hants*. London, Dulau & Co., Ltd., 1912.

were, I believe, found before the range and characters of *A. granulatus* were fully realized and were recorded in fact as *A. quadratus* simply on the strength of their granulation and general horizon. These records were, I believe, gradually transmuted into *A. granulatus* in consequence of an impression which prevailed for some time, as the result of putting together—

(1) Dr. Rowe's statement that all the Belemnites found by him in the old zone of *A. quadratus* on the Sussex coast proved to be *A. granulatus*, and

(2) My own knowledge that the Sussex coast sections included not only very long exposures of the whole of the zone of *O. pilula*, but also very considerable exposures of the lower part of the restricted zone of *A. quadratus*,

that *A. quadratus* did not extend outside the restricted zone of *A. quadratus* and was probably limited to the upper part of even that restricted zone, and that any *Actinocamax* from any lower horizon was presumably *A. granulatus*. When therefore I came to prepare the table of fossils in "The Zones of the Chalk in Hants" the material supplied to me included these four specimens as *A. granulatus*, and I tabulated them as such on the principle enumerated in the second paragraph of the introduction to the table. One of these specimens has since been demonstrated to come from a pit in the restricted zone of *A. quadratus* and so was probably really an *A. quadratus*, and if really an *A. granulatus* does not assist the theory of distinct ranges for these two Belemnites; and of the other three records one is a traditional record before 1890 from a pit now known to include the base of the restricted zone of *A. quadratus*, another is based on a specimen not sufficiently complete to be positively identified, and the third on a specimen that has long been lost sight of. These records do not therefore constitute any reliable evidence on the present question.

But whether Mr. Jukes-Browne was or was not relying partly on them, I regard the suggestion with dismay. My personal experience in Hants corresponds exactly with that experience of Dr. Blackmore in Wilts which Mr. Jukes-Browne (naturally) characterizes as exceptional, and I have two specimens from Sussex which I expect to prove that there also *A. quadratus* ranged down at least into the upper division of the zone of *O. pilula* and probably also into the lower, and I possess no evidence that *A. granulatus* occurs in the upper division of the zone of *O. pilula*.

But even if there are areas in which the boundary dividing the zone of *O. pilula* from the restricted zone of *A. quadratus* does seem to correspond with a line dividing the range of *A. granulatus* from that of *A. quadratus*, the contrary evidence of Hants and Wilts does not stand alone. A single pit at Bramford, near Ipswich, has yielded *A. granulatus* (determined by Mr. Jukes-Browne himself and recorded by him in *The Cretaceous Rocks of Britain*, vol. iii, p. 246) and *Belemnitella mucronata* (found by me, determined by Dr. Blackmore, and included by Mr. Jukes-Browne in the table on p. 247 of the last-mentioned work). There is therefore a possibility that the range of *A. granulatus*, already known to be a very long one, may

overlap even that of *B. mucronata*, and it is very dangerous to base any classification on the assumption that it never overlaps that of *A. quadratus*.

The next point to catch my eye is the tabulation of *A. verus*, *A. quadratus*, and *B. mucronata* as having absolutely distinct ranges in Belgium. In a paper by M. Rutot (Bull. Soc. Belge Geol., tome viii, pp. 145–194, 1894) it is strongly emphasized that in a division consisting of pure white chalk and known as the "craie de Triviéres" (and in one case, to judge from a section given, in an exposure of the upper part only of that subdivision) the three Belemnites above mentioned are found associated. Unless this statement has since been very thoroughly disproved it is dangerous to tabulate the ranges of *A. verus* and *B. mucronata* as separated by two whole zones.

The next point for consideration is the statement (previously alluded to) on p. 313 that it is a fact that the highest beds in the Yorkshire cliffs belong to the zone of *O. pilula*; in other words, that there is no chalk of the restricted zone of *A. quadratus* exposed in the Yorkshire cliffs.

Now it is obvious that if this statement ought to be accepted as an unquestioned fact, it cannot have been demonstrated in any earlier publication, and the argument proving it must be sought in Mr. Jukes-Browne's paper; and it would seem to be an essential element of such an argument that some test should have been established by which the boundary between the zone of *O. pilula* and the restricted zone of *A. quadratus* in Yorkshire can be determined and recognized with reasonable certainty. No such argument or test is directly stated, but it appears to be implied that the absence of *A. quadratus* has been treated as such a test. This is not a test for South England, and even if it has been absolutely demonstrated on the Yorkshire coast—and there is an immense difference in the case of *A. quadratus* between "has not been found" and "does not occur"—it remains to be proved that it is a valid and conclusive test for Yorkshire. This leads on to a point which goes to the root of the reliability of many of Mr. Jukes-Browne's instances of fossils which do occur in the zone of *O. pilula* but do not occur in the restricted zone of *A. quadratus*, and which is best explained by a concrete case. Mr. Jukes-Browne cites *Inoceramus lobatus* as occurring in the zone of *O. pilula*, but not in the restricted zone of *A. quadratus*. This citation must, from his general remarks, be based on statements in Mr. Woods' monograph. There we find *I. lobatus* recorded only from Yorkshire, but from many places in that county. How can any degree of reliability attach to the statement that this species occurred always below, never above, a line which has not yet been determined? This consideration would seem to rule out the employment of any specimens recorded from the old zone of *A. quadratus* in Yorkshire as evidence in establishing a stage break in the middle of that zone. I am afraid it also tends to the conclusion that it is dangerous to employ for that purpose many of the records from the South of England so employed by Mr. Jukes-Browne, although conditions are less

unfavourable there, as Mr. Jukes-Browne adopts, by reference to "The Zones of the Chalk in Hants", definitions of the boundary in Hants which, while not very precise, might well enable it to be identified in other counties in a cliff or good pit section. At the same time it is hardly likely that any collections from the old zone of *A. quadratus* made before 1911, when Mr. Griffith and I first published our proposed subdivisions of it, were either made or labelled with such close attention to the particular planes of division that we adopted, or otherwise so accurately labelled as to precise locality, that they can, except in rare cases, be now definitely referred to one of those subdivisions.

The difficulty is best shown by a concrete case.

Mr. Jukes-Browne credits the zone of *O. pilula*, but not the restricted zone of *A. quadratus*, with *Inoceramus tuberculatus* and *I. pinniformis* on the strength, according to his own showing, of Mr. Woods' citation of both these species from the zone of *A. quadratus* of Brighton and Yorkshire. The 'Brighton' specimen of *I. tuberculatus* was collected by Dr. Rowe, probably before 1900; the 'Brighton' specimen of *I. pinniformis* before 1871. It is quite possible that since the beginning of 1911 the exact spot at which *I. tuberculatus* was found has been pointed out by Dr. Rowe or identified from bearings furnished by him, and its position with reference to the divisions made by Mr. Griffith and myself (which are absolutely reproduced on the Sussex coast) worked out, and it is also just possible that the same has been successfully done with the 'Brighton' specimen of *I. pinniformis*; but it is not stated to have been done, and nothing less would justify the use of these 'Brighton' specimens in distinguishing the zone of *O. pilula* from the restricted zone of *A. quadratus*.

Another question which arises in connexion with the Yorkshire Chalk is whether, if the whole or part of a zone other than the restricted zone of *A. quadratus* can be identified as succeeding the zone of *Marsupites* in Yorkshire, that zone is properly labelled "zone of *Offaster pilula*".

Now it was long ago pointed out by Barrois that the highest Chalk of Yorkshire showed strong signs of affinity to the German Chalk, and Dr. Rowe has furnished us with plenty of evidence that during several Chalk epochs, one of them being the epoch succeeding the zone of *Marsupites*, there is strong evidence of restriction in the affinity between Yorkshire and South England, owing probably to a high submarine ridge between them. On the particular evidence that in the Anglo-Parisian basin the zone of *Marsupites* is succeeded by a zone which is characterized by *O. pilula* and does not contain *Scaphites binodosus*, that in the North German basin the zone of *Marsupites* is succeeded by a zone which is characterized by *S. binodosus* and does not contain *O. pilula*, and that in Yorkshire the zone of *Marsupites* is succeeded by a zone which contains *S. binodosus* in abundance but in which *O. pilula* is scarce, it seems highly probable that Yorkshire at that time was essentially an arm of the North German basin and that the Yorkshire zone should be termed the zone of *S. binodosus*, and that in an inquiry as to synchronism

in the Anglo-Parisian and North German basins Yorkshire fossils should appear in a different table from South English fossils, and that tests which are valid in South England may be quite fallacious in Yorkshire.

In the next place in the table on p. 372 the zone succeeding, as a 'continental' zone, the zone of *Marsupites* is given as the zone of *O. pilula* (on p. 369 it seems to appear as the "zone of *O. pilula* and *S. binodosus*"). It seems hardly prudent to ignore the part played by *S. binodosus*; and as *O. pilula* and *S. binodosus* are practically alternative in occurrence the conjunction 'or' seems the better one and the 'continental' zone should bear the name of "zone of *O. pilula* or *S. binodosus*". In the same table the Turonian is made to include the zone of *M. cor-anguinum* by what is obviously a printer's error of transposition of two brackets, but it is disconcerting as it stands.

Finally, a minor point of discord is to be found in the female gender of the varietal names of several varieties of *Echinocorys scutatus*. If they stood alone they could no doubt be absolutely justified on the ground that the name is an adjective whose nominative is 'var.', which stands for 'varietas', a feminine noun. But this line of defence is blocked by instances such as e.g. *Inoceramus inconstans*, var. *striatus*. It looks like a result of the use of two generic names of different genders for the same genus in different parts of the paper, while all the varietal names have been made to agree with one of them. It gives, however, a somewhat unfortunate suggestion of blunder on the part of the authors of the varieties.

It may not be inappropriate to take this opportunity of mentioning by way of postscript that I still retain the opinion expressed in *The Zones of the Chalk in Hants* that the subzone of *O. pilula* of that work would be best treated as a separate zone, and that I should have done so if I could have seen how in that case to deal with the subzone of *E. scutatus*, var. *depressus*; but it has always appeared to me impossible to unite the latter with the zone below it, and very difficult to endow it with zonal rank, and the only alternative was to unite it with the zone above.

Further, the plane which I have adopted as the top of my zone of *O. pilula* is one which is identifiable by palæontological (and often lithological) evidence of most exceptionally definite and easily recognizable nature, and it was hardly possible for a fieldworker, chiefly engaged on pits, to ignore it. But it is undoubtedly the case that the peculiar fauna of the subzone of abundant *O. pilula*, other than *O. pilula* itself, does not die out suddenly, like *O. pilula*, but gradually over a distance generally about 8 or 10 feet, and which in the Salisbury area is probably not less than the 25 feet necessary, according to Dr. Blackmore's measurements, to embrace the whole of the bed to which *Belemnitella lanceolata* is restricted, and which also contains *Aptychus leptophyllus* in abundance.

There is therefore substantial ground for the theorist to argue that the zone of *O. pilula* (or, which is practically the same thing, the subzone of abundant *O. pilula*) must be extended above the upper boundary which I have drawn for it. I have not, however, been

able yet in Hants or Sussex to trace in practice any easily recognizable line marking the general disappearance of this fauna or even that any two of its elements disappear simultaneously. At the same time if a means could be devised for including fossils from any beds in which this fauna lingers with those of the zone of *O. pilula* without sacrificing the field value of the upper boundary I have drawn, it would be a substantial improvement on any suggestion yet put forward.

III.—On some Chalk-pebbles from the Floor of the English Channel.

By A. J. Jukes-Browne, F.R.S., F.G.S.

IN 1908 Mr. R. H. Worth described a number of stones which had been dredged by Mr. T. R. Crawshay, of the Marine Biological Association, from the floor of the English Channel to the east and south-east of the Lizard.[1] These stones included a great variety of rocks such as granites, felsites, diorites, and other igneous rocks, gneisses, schists, slates, and quartzites, Devonian grits, Permian conglomerate, Triassic marl, sandstones of different kinds, Liassic limestones, hard chalks, and flints.

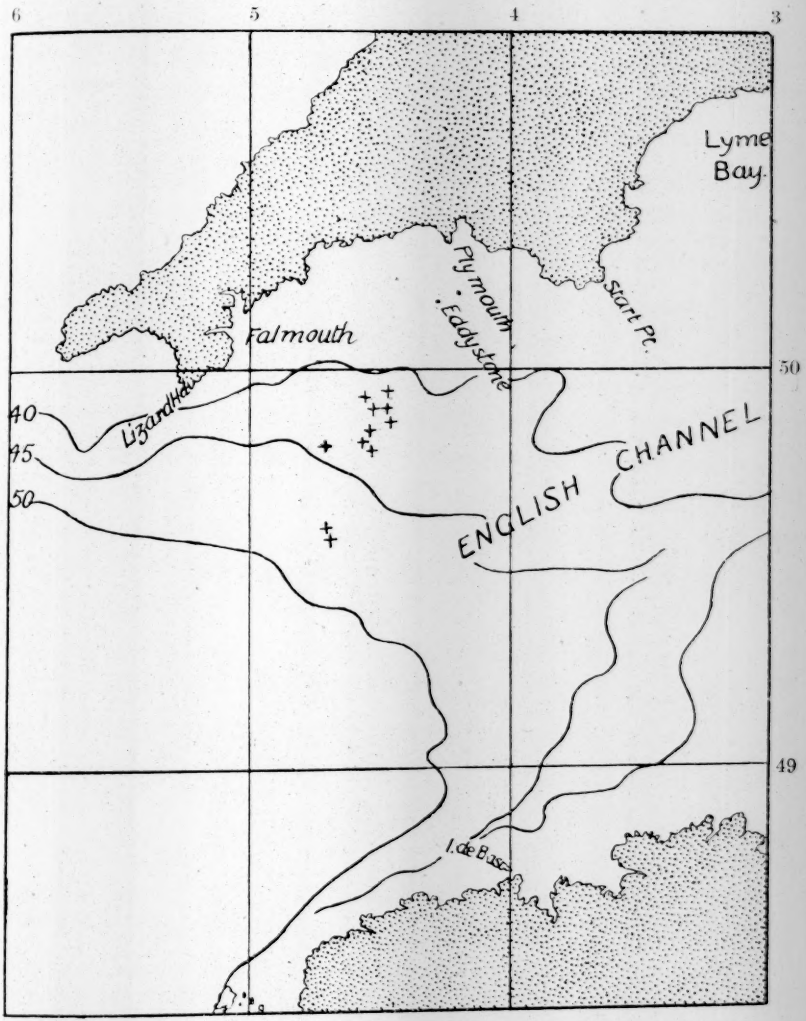
The majority of these stones and all the chalk-pebbles were obtained from depths between 40 and 50 fathoms in an area to the south of N. lat. 50° and about midway between the lines of 4° and 5° W. long. (see Map, p. 63). Mr. Worth has enumerated all the different varieties of rocks in this interesting assemblage, and has given particular descriptions of most of them from microscopical examination. Of the chalk-pebbles he observes, "a very hard yellow or cream-coloured chalk is of frequent occurrence; generally the exterior of the pebble is brown, and this colour extends some slight depth into the stone, getting less in intensity until it fades into the yellow or cream colour. Unless the stone happens to be much bored it usually requires a considerable blow to break it."

Mr. Worth prepared slides from five of these pebbles, and briefly mentions the composition of four of them, but describes the fifth in more detail. This pebble was about 3 inches long, stained orange-brown outside and yellow for a depth of 7 mm., all the inner part being cream-coloured. It included a nodule of green-coated chalk, the interior of which was reddish with cream-coloured markings, these latter proving to be borings made by some animal before embedment and filled with the material of the surrounding chalk matrix.

After describing a slice cut through this included nodule, Mr. Worth remarked that "the affinities of this yellow chalk appear to be with the 'Melbourn Rock' described by Mr. A. J. Jukes-Browne and later by the same author in collaboration with Mr. W. Hill", but he adds, "whether lithological similarity in this case implies identity of age may be doubtful." He does not seem to have made comparisons with any other part of the Chalk, and does not even mention the possibility of its being Chalk Rock.

[1] Journ. Marine Biol. Assoc. for 1908, p. 118.

As the description and photographs of this chalk-pebble seemed to me to agree much more closely with the Chalk Rock than the Melbourn Rock, and as Mr. Worth had not ventured to refer the



Map showing the spots, marked by crosses, where chalk-pebbles were found. The lines in the Channel are the contours of 40, 45, and 50 fathoms.

other specimens to any particular horizon, I asked him if he would allow me to examine the slides, and whether he could send me some of the other pebbles which had not yet been sliced. In response to

this request he kindly sent me the five slides, as well as two others subsequently made, and a few of the other pebbles. Some of the latter were too much eaten away by boring animals to allow of cutting, but Mr. W. Hill has succeeded in making slides from six of them, and to his kindness in so doing I owe the opportunity of examining their structure. Mr. Hill has also examined all the slides and concurs in the conclusions at which I have arrived.

Mr. Worth's Slides.—It will be convenient to deal with these first. M. 14*a*: This is the specimen which was specially described by Mr. Worth, and it is undoubtedly comparable with the Chalk Rock of the midland and southern counties and with the rocky beds which occur in the zone of *Holaster planus* in Devonshire. No one who was familiar with the structure of the different zones of the Chalk could mistake it for Melbourn Rock. It exhibits the same variety of included organic fragments which is so constant a character of the Chalk Rock, and it contains numerous small grains of yellow-green glauconite, a mineral which is of frequent occurrence in the Chalk Rock, but is never present in the Melbourn Rock.

Again, the material of the included nodule differs from that of the surrounding substance in the same way as the included nodules of the Chalk Rock differ from the mass of that rock. In each case the component materials are the same, but there is a larger proportion of the fine-grained matrix in the nodule than in the surrounding chalk, and rather fewer of the larger fragments, such as pieces of shell and plates of Echinoderms. In other words, the nodules appear to be portions of the same deposit, but sifted by current action and indurated before being embedded in a fresh deposit.

The included nodule in the dredged pebble contains grains of glauconite, and it is in every respect similar to those of the Chalk Rock and different from those in the Melbourn Rock.

Mr. Hill and I possess slides of Chalk Rock from Cruxton, near Maiden Newton in Dorset, from Combe Beacon, 3 miles north-west of Chard, from Membury, north of Axminster, and from Pinhay, near Lyme Regis. The first two are typical Chalk Rock with glauconite grains, and are similar in structure to the Channel pebble. The third does not contain glauconite, but is an interesting slide, as it shows areas of typical Chalk Rock material passing gradually into others with a larger proportion of fine matrix and fewer shell fragments, the organic remains in the latter being chiefly foraminiferal cells and 'spheres', with sponge spicules, small Foraminifera, and shell debris (as in the nodules above-mentioned). The rocky chalk at the base of the *planus* zone at Pinhay shows the usual characters of Chalk Rock, but the glauconite grains are small.

The other four pebbles cut by Mr. Worth differ from that above described in not containing any glauconite and in having a larger proportion of the fine matrix with its complement of spheres and foraminiferal cells. Three of them resemble one another and the first one (M. 14*a*) in the variety of their organic contents, and consequently I think they may be referred to the zone of *H. planus*.

These slides may be described as showing a fine chalky matrix through which are scattered many cells and spheres, with a large

number of small shell fragments, which always include some of Echinoderm plates and ossicles, as well as some *Inoceramus* prisms. There are also some perfect but small Foraminifera, such as *Textularia*, *Rotalia*, and small *Globigerina*; and a variable number of sponge spicules replaced by calcite and of cavities which have been occupied by spicules. Here and there larger pieces of shell or Echinoderm plates are to be seen.

They differ slightly from one another in such a manner as different pieces of chalk from the same zone might be expected to vary. Thus 21*c* and 26*a* have very few *Inoceramus* prisms and not many sponge spicules, while 72*b* is full of spicules and there are few prisms; 26*a* is also notable for containing a large piece of Echinid plate and a fragment of composite Polyzoan zoaria.

These slides agree very closely with one cut from a bed of hard rocky chalk in the middle of the zone of *H. planus* at Cruxton in Dorset, the No. 3 of the section given in *Cretaceous Rocks of Britain*, vol. iii, p. 119. This rock has the usual variety of contents, but most of them are small, and neither *Inoceramus* prisms nor sponge spicules are numerous. Further, there is no glauconite, so that its composition is really just the same as that of the 21*c* and 26*a* pebbles.

They also have much resemblance to the material of a piece of the *planus* zone obtained by Mr. A. C. G. Cameron from Annis Knob, near Beer. In the slide prepared from this the shell fragments are all small, except one large piece of Echinid plate, but sponge spicules are abundant, *Inoceramus* prisms fairly numerous, the perfect Foraminifera small, and there is no glauconite; so that this compares very closely with M. 72*b*.

Lastly, they are comparable with a slide cut from a piece of hard chalk from the zone of *Micraster cortestudinarium* at Pinhay, near Lyme Regis, for which I am indebted to Mr. A. W. Rowe. This is crowded with cells, spheres, small Foraminifera, and small shell fragments, among which bits of Echinoderm shell are numerous; there are many sponge spicules, but not much *Inoceramus* debris. One or two small grains of glauconite occur, and the specimen must have come from the base of the zone, the structure being like that of the *H. planus* zone.

The slide which differs from the other three is labelled M. 72*a*. It contains very few spicules and a larger number of *Inoceramus* prisms, as well as many irregular fragments of shell, the derivation of which it is difficult to recognize. In this respect it resembles two other pebbles which will be mentioned hereafter.

Pebbles not previously cut.—Six of these have been sliced and mounted by Mr. Hill, but one of them turns out to be of some other kind of limestone, not a Cretaceous chalk, and two others are so much perforated (Nos. 17 and 25) as to be of little use. The following are brief descriptions of the microscopical structure of the five chalk-pebbles.

No. 58. This is a compact chalk, the matrix of which is nearly as full of recognizable organic fragments as the chalk of the *H. planus* zone. There are plenty of cells, spheres, and small shell fragments, some of which appear to be broken and eroded *Inoceramus* prisms, but there is little Echinoderm debris and very few Foraminifera or

sponge spicules. Of the larger fragments the most conspicuous are pieces of Polyzoa, some of them being unusually large, while many of the smaller and irregular shelly fragments are probably Polyzoan remains.

No. 41. This resembles the above and has about the same variety of contents. The included fragments are mostly small, consisting of spheres and small shell fragments with a few small *Textularia* and *Globigerina*. There are two or three pieces of *Inoceramus* shell showing prismatic structure and some isolated prisms; also some pieces of Echinoderm plates and many fragments of Polyzoan zoaria, but of sponge spicules there are very few.

No. 35. This has a larger proportion of amorphous matrix with scattered spheres and cells and a fair number of sponge spicules, but not many *Inoceramus* prisms. Small Foraminifera are numerous with some of larger size. The larger fragments are mostly pieces of Polyzoa and fragments of Echinoderms are scarce.

No. 25. This is a similar chalk to the last, but the slice is small, and the area of original material is so limited, from the extent of perforation, that little can be said of it except that sponge spicules and Foraminifera are numerous.

No. 17. This has been so much perforated that only small portions of the original rock remain. It was a chalk of the same compact kind, the proportion of amorphous matrix being large and all the recognizable particles small. There are several *Textularia* and a few shell fragments.

The first two of these slides (Nos. 41 and 58) and that of M. 72*a* may be considered together, as they consist of similar material, but it is on the first two that we must rely for comparative purposes, because the slice of 72*a* is a small one. In these two slides the number of fragments of the cellular zoaria of Polyzoa is a conspicuous feature which cannot be exactly matched by any chalk known to Mr. Hill or myself. But if the presence of these fragments is left out of account the enclosing material is comparable with the chalk of two different horizons in Devon and Dorset. These are the higher beds of the zone of *Rhynchonella Cuvieri* and certain rocky beds in the zone of *M. cortestudinarium*.

Until we had examined slides cut from the hard nodular beds in the higher part of the *R. Cuvieri* zone at Beer Harbour neither Mr. Hill nor I was aware that they possessed special characters and were so similar in composition to beds of a much higher horizon, i.e. to certain beds of hard chalk-limestone which occur in the zone of *M. cortestudinarium*, (1) at Annis Knob above Beer Harbour, (2) at Cruxton, near Maiden Newton, and (3) near Notton in the same neighbourhood. The general composition of the two sets of beds is the same, there being nearly the same proportion of cells and spheres distributed through the matrix, with a relatively small number of fragments derived from Inocerami or Echinoderms. Both contain many Foraminifera and a variable number of sponge spicules, and neither includes any glauconite grains.

The differences are that in the rock-beds of the *cortestudinarium* zone there is generally a larger number of the minute cavities left by

the dissolution of siliceous spicules, that the Foraminifera are in rather greater number and variety, and that there is a larger proportion of small shelly particles in the matrix, exhibiting much variety of outline as if derived from several different kinds of organisms. On the other hand, the *Cuvieri* beds generally contain spherical areas, filled with amorphous matrix, which represent the spaces once occupied by Radiolaria, while in the higher zone such spheres are absent or very rare.

It should also be mentioned that the ordinary chalk of both zones has a much less variety of contents, that of the *Cuvieri* zone generally containing much *Inoceramus* debris but few spicules, while in the *cortestudinarium* zone the reverse is the case. Moreover, in the latter there is generally a larger proportion of amorphous matrix with fewer cells and spheres. It is only in the hard rocky layers occurring in that zone in Dorset and Devon that cells and spheres are so abundant.

When the slices cut from the pebbles 41, 58, and 72*a* are compared with those above-mentioned it is seen that they bear a rather greater resemblance to those from the beds in the *Cuvieri* zone than to those from the *cortestudinarium* zone. They differ, however, from the former in the absence of any traces of Radiolaria, and also of course (as previously mentioned) in the presence of large fragments of Polyzoan zoaria. It is possible that these two points of difference explain one another, and that the chalk of the pebbles was formed in a locality where Polyzoa were abundant and Radiolaria did not exist, while a little further north the conditions were unfavourable for Polyzoa but lay in the track of a current carrying Radiolaria.

The only true chalk which I have found to contain much debris of Polyzoa is a bed of yellowish rocky chalk forming the base of the *Cuvieri* zone in a quarry near Branscombe Church between Sidmouth and Beer. This bed differs from the basement bed seen in the cliffs by the absence of quartz and glauconite grains, its general composition resembling that of the pebbles 41 and 58 and including several fragments of Polyzoan framework, but it differs in containing a much larger quantity of *Inoceramus* debris and in the greater abundance of large sponge spicules, as well as by including many casts of Radiolaria.

The pebbles have no resemblance to the 'Beer Stone', which is a coarse shelly limestone composed mainly of fragments of *Inoceramus* shell, nor to the beds which overlie that stone in Beer Quarries, which are all very shelly, even the highest compact rock-bed being full of *Inoceramus* and Echinoderm fragments.

Pebble 35 differs from the others in having a much larger proportion of amorphous matrix, with fewer cells and spheres and a greater number of sponge spicules. There is, moreover, a greater number of Foraminifera and more variety of small shelly fragments. In all these respects it more nearly resembles the ordinary nodular chalk of the *cortestudinarium* zone, but it contains in addition fragments of a cellular skeleton like that of Polyzoa.

The pebbles 17 and 25, so far as the characters of the component chalk can be discerned in the small areas which remain, are of similar

material to 35, and the fact of their being so riddled with the cavities made by boring animals points to their having consisted of a less hard kind of chalk, and is consistent with their attribution to the ordinary tough chalk of the *cortestudinarium* zone.

From the preceding descriptions and comparisons it will be seen that the pebbles of hard chalk which have been obtained by the Marine Biological Association from the floor of the English Channel seem to be referable to hard beds in the zones of *R. Cuvieri*, *Holaster planus*, and *Micraster cortestudinarium*. This is really what might have been expected from a consideration of the component beds of the Chalk in Devon and Dorset, the most persistent hard beds in these counties being found in the zones above-mentioned.

It is not surprising that nothing like the Melbourn Rock can be recognized among the pebbles, because in its typical aspect it does not reach so far west as Devonshire; neither ought we to expect anything exactly like the Beer Stone to occur among them, for that is entirely a local development even in Devonshire, as it only occurs between Beer and Branscombe on the coast and again at Sutton Barton, near Offwell, 6 miles to the north. Hence the Beer Stone must have been accumulated as a bank of shell-sand little more than a mile in width, but possibly 8 or 10 miles long from north to south. Lastly, it is not surprising that chalk formed 60 or 70 miles farther south should possess some peculiar and special features of its own.

The identification of these chalk-pebbles with beds occurring in the zones above-mentioned raises some interesting questions. If they have been derived from the destruction of chalk in situ we may infer that the Turonian and Senonian deposits extended southwards across the whole of South Devon and the adjacent Channel area as far south as lat. 49·50, which is about that of Valognes, in Normandy. We have then to ask whether the Cenomanian and Selbornian deposits which underlie the Turonian in Devonshire are likely to have had a similar extension.

Mr. Worth has assumed that the deposits from which the pebbles were derived did occur within the area in question, and I think he is justified in the assumption, but it may be well to give reasons for this belief. Such a varied assortment of pebbles, if transported to their present position, could only have been carried there in one of two ways; either by rivers flowing over a land surface or by floating ice.

These pebbles lie on the northern slope of the Channel floor, not in a depression which might be regarded as a portion of a submerged river valley (see Map, p. 63). The only large river which is likely to have brought them would be a continuation of the Tamar and Tavy, and such a river may have existed in Eocene times, or might in Miocene time have obtained them from Eocene gravels. Now ancient gravels which are possibly of Eocene age do occur on Cattedown, near Plymouth, and have yielded a piece of Lias limestone but no chalk-pebbles; neither do such pebbles occur in the other Tertiary gravels of Devonshire, so that this source is improbable.

That they should have been transported by floating ice during the Glacial epoch seems still more unlikely, for chalk-pebbles could not

have been picked up along the shores of Cornwall or Devon, nor from those of Brittany. We should have to suppose a drift of ice from the east bringing stones from Normandy or from Dorset; but from these localities we should expect the debris of various Jurassic limestones which do not occur.

The assemblage of sedimentary rocks indicated by the pebbles is, in fact, just that which would be likely to coexist on the ground: it points to the superposition of Cretaceous deposits on Lias, Trias, and Permian, which is just the actual superposition in Devonshire. I agree therefore with Mr. Worth in regarding these pebbles as relics of formations which extended into the area of the Channel between Cornwall and Brittany, and as evidence on the strength of which we may discuss the probable extension of the several stages which appear to be represented.

The Selbornian Sands, which are only about 100 feet thick near Sidmouth, may have thinned out in a distance of 70 miles and in the direction of a land-surface; or they may have passed into soft and easily destroyed sands without cherts or hard calcareous beds. It is quite possible, however, that some of the so-called *flints* which Mr. Worth describes as the commonest kind of pebble on the Channel floor may really be *cherts*. This is particularly probable in the case of those which contain grains of quartz and glauconite, as in 62*b*, which was specially described by Mr. Worth, for such grains are rarely found in the flints of Turonian or Senonian Chalk.

The Cenomanian of Devonshire is of small thickness (from 3 to 18 feet) and consists of quartziferous limestones which indicate a proximity to land, though this land may have been an island on the site of Dartmoor. The persistence of Cenomanian deposits through Normandy makes it very likely that they continued for a considerable distance farther west, but only in the form of soft sands, which, however, may have contained cherts. The absence of any pebbles comparable with the hard quartziferous limestones of Devonshire makes it probable that if the Cenomanian did extend into the area in question its deposits were of the French and not the English type.

That the whole of the Turonian stage extended into this part of the Channel area is very probable, though it cannot yet be said that the pebbles afford positive evidence of it, because none of them are quite identical with any Turonian chalks in Devon or Dorset. If Nos. 41, 58, and 72*a* were really derived from the zone of *R. Cuvieri*, the assemblage of organisms prevailing at that time in the Turonian sea south of lat. 50 was not quite the same as that living in the area to the north; for Polyzoa were abundant and Radiolaria were absent or rare, while the reverse was the case to the northward.

The most important and at the same time the most indubitable identification is that of the Chalk Rock, for its discovery proves that at the epoch of its formation the conditions in this southern area were the same as those prevailing throughout the South of England. Incidentally also it makes it nearly certain that the higher part of the Turonian, i.e. the zone of *Terebratulina lata*, had a similar extension, because the epoch of the *planus* zone is believed to have been one of

upheaval, and consequently the existence of Chalk Rock in its normal aspect implies the previous formation of some equivalent of the *T. lata* zone.

That the zone of *H. planus* should be followed by that of *M. cortestudinarium* is only natural, and if a larger number of the pebbles were examined fragments of some of the rocky beds of this zone might perhaps be more certainly recognized. In those which do appear to belong to this zone it is interesting to find that remains of Polyzoa are again a conspicuous feature.

It is to be hoped that the Marine Biological Association will continue the work of exploring the floor of the Channel and will recover pebbles from positions still farther south and west, for it can hardly be doubted that they have a wider distribution in those directions than has yet been ascertained. Actual evidence of this and farther investigation of the flints and cherts would be very desirable.

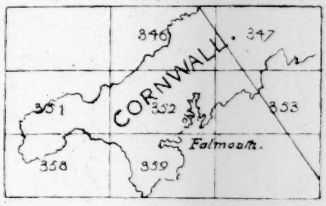
IV.—On the General Geological Structure of Western Cornwall, with a Note on the Porthluney–Dodman Section.

By Upfield Green and C. Davies Sherborn.

IN attempting an explanation of the structure of Western Cornwall it seems fairly evident that the first step should be a study of the coast sections, for the interior of the country is so folded and buckled that it is quite bewildering in its complexity. The natural sections most useful for this purpose are those of Black Head to Gorran Haven, St. Michael Carhayes to the Dodman, Falmouth to the Manacles, and Trewavas to Mullion, since all these sections cross the lines of strike more or less at right angles. It soon becomes abundantly clear that the complexity of folding exhibited by the rocks is but the detail of greater movements and need not seriously detain us. In 1908 Upfield Green expressed our views on those greater movements in the ninety-fifth report of the Trans. Roy. Geol. Soc. Cornwall, and endeavoured to show that the great Hercynian movements had involved Cornwall, throwing the country into three east and west anticlinals with sinuous outcrops, which anticlinals had gradually been forced over to the north into overfolds. These folds have been further complicated, distorted, and confused by local minor bucklings shown by the strata on every side. In the paper quoted a map was given showing the major anticlinals, and one section across the country from Newquay to Portholland was added to explain our views on the subsequent overfolding of these anticlinals to the north. In December, 1912, we jointly published a note on the Trewavas–Mullion section, which we had written in May, 1910, and this second section corresponded in a striking manner with our first from Newquay to Portholland.

For the purpose of clearing up our views on Cornwall it is necessary to publish a third section, that from Porthluney to the Dodman, for this fits on to the southern end of Green's Newquay to Portholland section, and completes it for 2½ miles further south.

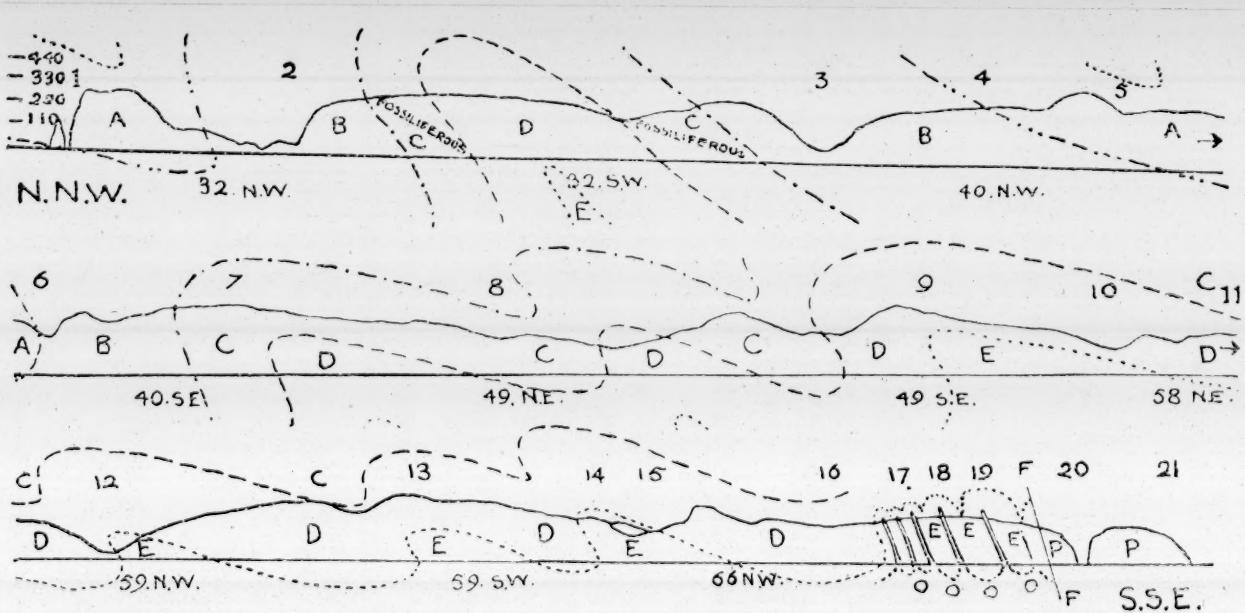
For facility of reference it will be necessary to examine the following sheets of the new series Geological Survey map of England and Wales, as it is obviously impossible to reproduce such a map in this Magazine.



Key-map to sheets of Geological Survey Map.

This map agrees so closely in mapping with the results of our own twenty years observations and is so confirmatory of our views that we may well refer to it. The one serious error is the line of 'conglomerate' dividing the 'Grampound Grit' and the 'Porthscatho Beds' almost at right angles to their strike on Sheet 353. But as those two deposits are one and the same, this obvious error need not detain us.

At the foot of Sheet 353 is a section from Porthluney to the Dodman, and this section will suffice precisely for our purpose. We accept it, for it corresponds with our own observations, although we place our own interpretation upon it. It will be noted that there are several exposures of quartzite. These are the quartzites that have yielded Ordovician fossils at Gorran, Diamond Point (Porthluney), and Carne, and upon the age of which every observer is agreed. The bands are definite although broken up, pushed about, and dismembered, and can be traced from Gorran through Porthluney to Carne and are seen again westwards at Nare Point (Helford River) and thence across the country to Cury, north-east of Mullion. This quartzite is the oldest stratified deposit in Cornwall, except perhaps the Dodman phyllites and the Lizard rocks, with which we are acquainted, and we have never seen the bed upon which it rests, unless the peculiar greenish-black quartzite containing *Orthis calligramma* (Brit. Mus. and Mus. Pract. Geol.), occasionally seen as boulders in and near Catasuent Cove, may represent a lower bed. Now let us interpret this section. To the north, at a point marked Porthluney, is a little canal cut to drain the Carhayes Lake. A low cliff borders the eastern side of the canal composed entirely of Porthscatho Beds, though we believe the first few yards of the northern end show Veryan Beds at the base of the cliff. Passing out of the canal and proceeding south along the beach, we encounter the coarse 'basal conglomerate' of the Porthscatho Beds, followed by a mass of igneous rock (marked D) which has broken through and disturbed the beds. At this point the interest begins, for we find undoubted Veryan Beds beyond the igneous intrusion, containing lenticles of fossiliferous Silurian rocks and continuing unaltered south to the further horn of Catasuent Cove. Beyond Catasuent Cove the coast for three-quarters of a mile is inaccessible to us,



Generalized Section across Cornwall from Trerathick Point (N.) to the Dodman (S.). By Upfield Green and C. Davies Sherborn. 1 : 63,360 ; 1 inch = 1 mile ; 1 inch = 880 feet.

A. Staddon = Coblenzian.
B. Meadfoot = Taunusian.
C. Falmouth)
D. Porthscatho Gedinnian = Lower Devonian.
E. Veryan)
O. Ordovician quartzites.
P. Phyllites of the Dodman.

1, Trerathic Point ; 2, stream ; 3, stream ; 4, Bosoughan Road ; 5, railway ; 6, stream ; 7, road ; 8, millpond ; 9, Grampound Road Railway ; 10, stream ; 11, road at Barteliver Quarry ; 12, River Fal and Old Halebote Quarry ; 13, Pencoose ; 14, Polgrain ; 15, road and stream ; 16, Portholland and Porthluney ; 17, Catasuent Cove ; 18, Greeb Point ; 19, The Clitters ; 20, Hemmich Beach ; 21, The Dodman. The "32 N.W.", etc., indicate the sheets of the six inch map.

but we are quite satisfied from our knowledge of the land surface with the Survey section on which we base these remarks and accept it all as coloured, namely 'Veryan', up to the Dodman phyllites, recognizing that it would be progressively altered by compression as it was crushed and forced against the Dodman mass. Now it is clear that these Veryan Beds are interrupted here and there by quartzites which contain Ordovician fossils, and it is equally clear from the ground, the mapping, and the section that these quartzites appear at intervals up to the mass called 'The Clitters'. They represent in our judgment the crushed and broken anticlinal folds of a once continuous bed, the synclinals of which are filled with Veryan Beds more and more altered as we pass south till they are brought up short against the Dodman mass, which may be considered to be of earlier age and part of the old ridge of rocks represented on the west by the Lizard area.

Having now given our views on this section we may briefly sketch the general structure of the country, using the Survey maps as our illustration. The order of succession of the sedimentary rocks from above downwards is Meadfoot, Falmouth, Porthscatho, Veryan, Quartzites, as stated and defined in GEOL. MAG., December, 1912, p. 560. All these beds fan out as we proceed westwards, and the broad edge of the Porthscatho Beds is altered by the granite mass which comes in contact with it into the 'Mylor Beds' of the Survey. It is clear, therefore, that the 'Mylor Beds' have little claim for separate recognition. The beds, originally horizontal, were forced into anticlinals, then into overfolds, and finally crammed and crushed into the endless minor contortions so puzzling in the field. But they have yet retained their original sequence, and, though once present, some Silurian rocks have disappeared in the smash, and fragments of the Ludlow, Wenlock, and Woolhope Beds still remain as lenticles of fossiliferous limestone in the Lower Devonian beds of Perhaver, Porthluney, Veryan, Porthalla, and Mullion. From *all* of these places we have no doubt recognizable Silurian fossils will eventually be found to offer further support to these opinions.[1]

V.—The Upper Trias of Leicestershire.

By A. R. Horwood.

3. Stratigraphy (*continued*).

(WITH A TEXT-MAP.)

(*Continued from p.* 32.)

(2) *Measham and Orton District.*

THIS district is bounded on the north by the Coalville and Ashby line, on the west and south by the county boundaries, on the east by the Shackerstone and Market Bosworth lines. In the north are exposures of Coal-measures, Permian breccias, and Bunter, which the Trias in turn rests upon unconformably. The Lower Keuper

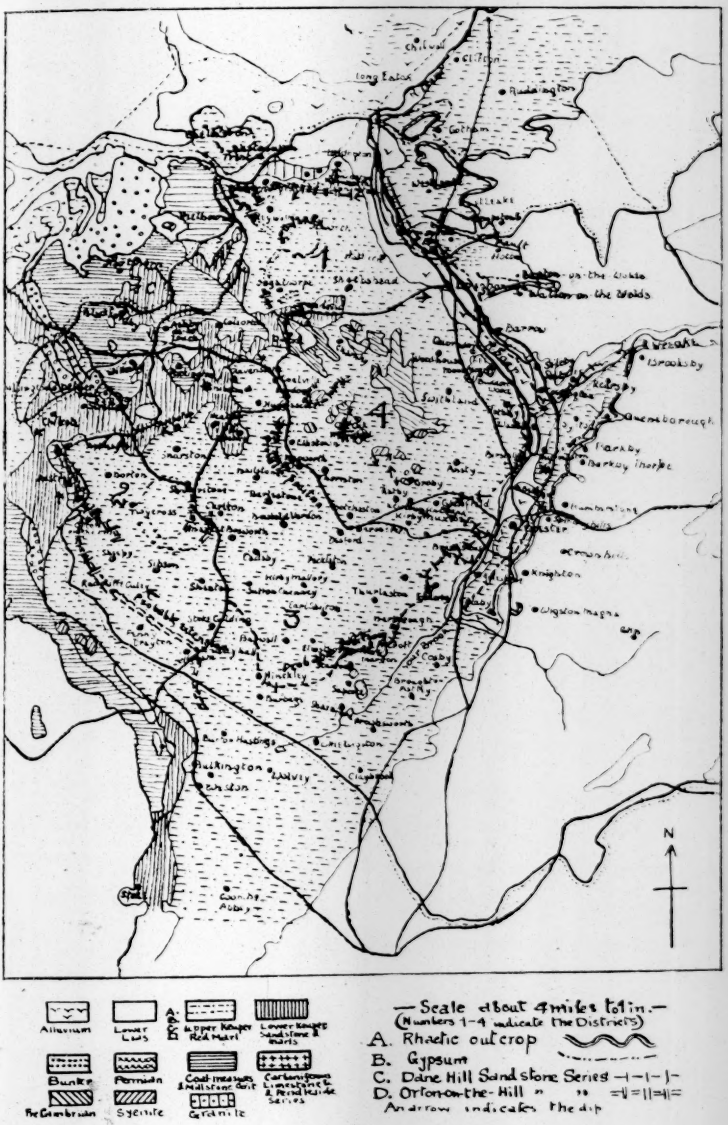
[1] [When staying at Mullion, Cornwall, in 1906, I found a perfectly recognizable trilobite when going down the path to Pollurian Cove, but its importance escaped me, and I did not preserve it, much to my regret.—H. WOODWARD.]

forms a long tract on the west not more than two miles in breadth, forming a good feature, the sandstones giving rise to scarps, whilst the Red Marl occupies the rest of the district to the east. On the south-west beds of sandstone form marked features, which also give rise to bold escarpments, whilst the Red Marl itself constitutes a uniform plateau with little or no variation in heights. There are few exposures in the marls, which on the extreme east are covered by a mantle of Boulder-clay and sands. The River Sence and the Sence Brook, however, cut down to the lower parts of the Red Marl, and a good deal of alluvium fills the valleys to the south. The altitude over most of this ground rises uniformly above 300 feet, and in some parts to over 400, rarely sinking below 250. A ridge of hills is formed by the Orton Sandstone striking north-west and south-east, and another ridge meets it at right angles from Market Bosworth.

The surface of the Bunter was apparently much eroded before the deposition of the Lower Keuper which lies in hollows of the pebble beds, and abuts the ridges unconformably. Both the Red Marl and Lower Keuper Sandstone respectively overlap the Bunter, and the former the latter in this district. There is a noticeable thinning out of the Bunter from west to east, and also of the Lower Keuper Sandstone. The Red Marl seems to thicken in this direction, however. The pre-Triassic surface in this area (and No. 3, to which the following remarks also apply) shows that Trias rests on rocks older than the Coal-measures in many places, indicating concealed ridges of Charnian and Cambrian beds between Warwickshire and Charnwood Forest. In this way we should expect to find evidence of undulation in the overlying strata and of flexures, but they are not clearly indicated unless it be where the sandstones about Orton crop out and give rise to a series of sinuous outcrops. Molyneux noticed years ago in the neighbourhood of Burton-on-Trent the undulatory bedding of the Red Marl in that direction, so that there are probably similar features hitherto unrevealed in this area. The existence of strain shadows in the grits and quartzites of the Permian breccias of this district, as Brown suggested, indicates their derivation from folded rocks.

Borings at Sapcote Freeholt and Elmesthorpe and at Market Bosworth reveal the presence of Cambrian rocks similar to the Nuneaton Series, so that a ridge striking north-west and south-east extends between that point and Charnwood Forest, cutting out the Coal-measures which over this area were deposited only in little shallow basins as at Elmesthorpe and to the south-east and north-west of Rugby. The existence of Stockingford Shales at Crown Hill, as proved in the boring at 800 odd feet, shows that another ridge sets in in that direction, and probably the syenites of Croft, Enderby, etc., are intrusive through the same beds. They moreover overlie a south-easterly extension of the pre-Cambrian rocks of Charnwood Forest, which extend southwards as far as Orton and Bletchley, if not further south. Thus both pre-Triassic and Triassic rocks south and south-east of Charnwood Forest are like the Coal-measures banked against ridges of Charnian or Nuneaton older rocks, or deposited in hollows in their numerous ramifications.

SKETCH-MAP OF WEST LEICESTERSHIRE, SHOWING THE UPPER TRIAS AND ASSOCIATED FORMATIONS WITH SANDSTONE AND GYPSUM OUTCROPS.



Photographed by A. Newton from a sketch-map of the Upper Trias of Leicestershire to show the general outlines of the district and the localities referred to in the text.

The Bunter beds seem to die out in the neighbourhood of Market Bosworth, being proved in the King's Hill boring. The age of the movements causing these foldings parallel with the Charnwood and Nuneaton ridges is post-Carboniferous, for both the older rocks and the Coal-measures are affected. Moreover, the latter were greatly denuded before the Permian breccias were deposited. The latter, too, are not influenced by these folds, so that they must be, as Browne states, pre-Permian. In this area the Lower Keuper sandstones rarely exceed 150 feet, and they thin out to the east. They resemble the beds in District (1), consisting of sandstones with marly beds between.

In the north-west the sandstones form high ground, making a ridge from Measham to Willesley. At Willesley this ridge rises to 450 feet, running north and south, and the sandstones crop out. At the south end of the Park they terminate abruptly, the Coal-measures being faulted up against them and the Permian breccias below, but the fault is overlapped by the two later beds. From here to Measham the Lower Keuper forms a good feature further east.

Further south in the Mease Valley a boring at Coton Park Colliery (250 O.D.) showed the Lower Keuper Sandstone to be 63 feet thick, overlying 228 feet of Bunter. At Netherseal, north of the River Mease, the outcrop bifurcates, striking west, and is cut out by a fault at Gunby Lea (south-west by north-east). At the Colliery it is obscured by Boulder-clay, but in the No. 1 boring Trias and Permian to a depth of 263 ft. 6 in. were pierced 1,000 yards south-east of Grange Wood House (256 O.D.). To the north-west at Caldwell the sandstone is predominant, massive beds with marly partings dipping south-west at 5 degrees being cut through in the colliery branch-line.

At Stretton-en-le-Field, east of the River Mease, in a boring at Saltersford, 2 feet of Marl under 9 feet of sand and gravel overlaid drab rock and brown bind, etc., and in another boring 10 feet of soil, sand, and gravel overlaid 18 ft. 1 in. of Red Marl and brown and grey rock.

Southward in the Chilcote boring (270 O.D.) the Trias was 704 feet thick, there being 600 feet of Bunter with twenty-one beds of conglomerate or red sandstone with pebbles and 70 feet of Lower Keuper Sandstone (or 100 feet perhaps), with 30 feet of Permian breccia overlying 300 feet of Coal-measures with no coal-seams. At Appleby No. 1 boring, White House, 578 feet of Trias, with probably some Permian, overlaid 396 feet of Coal-measures. The second boring at Bird's Gorse, Side Hollows, appears to have passed through 110 ft. 9 in. Lower Keuper sandstones and marls, 333 ft. 9½ in. Bunter, lying over Coal-measures with coals. A third boring at Appleby Hall, near Roe House, passed through 154 ft. 3 in. marls with gypsum and 455 ft. 3 in. of sandy beds without pebbles, some of which as in the other borings may be Permian and the rest Bunter. The Bunter thus thins out and becomes abnormal within a very short interval. About Measham it is overlapped by the Lower Keuper sandstones, which crop out in the brickyards to the east of the station. In one place 4 feet of Lower Keuper Sandstone is seen to overlie

Permian beds at this point. East of Measham it forms a broad outcrop, however, and both marls and sandstones are distinguishable, whilst towards Willesley it forms a striking ridge. The general dip is to the south.

Borings at Snarestone (310 O.D.) show 80 feet Lower Keuper Sandstone, 47 feet Bunter, and 96 feet of Permian, above Coal-measures. In No. 1 boring there was 45 feet of Lower Keuper, 70 feet Bunter, 38 ft. 6 in. Permian, and in No. 2 on the Bosworth Road, near the aqueduct, 78 ft. 9 in. Lower Keuper, 121 ft. 3 in. Bunter, overlying Coal-measures. East of the River Mease the Lower Keuper sandstones and marls here extend in a ridge to Normanton, flanking the Mease on the opposite side of the Willesley ridge. This ridge extends to Swepstone, and northward to the Burton line at Breach Hill, where they repose directly on Coal-measures in the cutting, no Permian beds intervening. Along this ridge the sandstones crop out and towards Normanton rise to an altitude of over 450 feet. To the east they are covered by Red Marl, the outcrop diminishing around the Altons.

At Packington, the most easterly occurrence of Permian breccias, unconsolidated and containing slate fragments, waterstones overlie and overlap the breccias. At Hugglescote (514 O.D.) a boring showed soil and clay 1 ft. 6 in., marl and sandstone 200 ft. 3 in., of which 96 ft. 11 in. is probably in Red Marl. There was here no conglomerate at the base of the Lower Keuper, but a pink mixture overlies Coal-measures. In the brickyard at Heather a section formerly showed 37 feet of Keuper Sandstone overlying 1 foot of conglomerate and Coal-measures. In the south-east there was more sandstone. The upper beds were found to pass gradually into marl, making their junction doubtful. In the Colliery it was shown that there was an extension of the Cole Orton fault, of 20 – 25 yards, bringing the Lower Keuper Sandstone down close to the stream. Outside this area the Lullington boring (275 O.D.) passed through 1,190 feet of Trias, with probably some thickness of Permian and Upper Coal-measures in the lower 547 feet underlying a doubtful thickness of Bunter of unusual type. Above this there was apparently 155 feet Lower Keuper sandstones and marls and 488 feet of Red Marl. These thicknesses are only approximate, since the limits of each division are in this area difficult to define. This is especially so in the case of the Red Marl, the boundary of which with the Lower Keuper between No Man's Heath and Appleby and Astrey to the south is not clear, though beds of sandstone in the Lower Keuper alternate with the marls, and to the east the Red Marl makes a feature which enables a boundary to be fixed between the Upper and Lower Marls, the latter predominating here. In the direction of Shuttington the outcrop widens and there are some sandstone horizons, which are traceable for some distance, though they ultimately die out, and the ground resumes a typical Red Marl appearance, though it is heavier than the latter. These flaggy beds are exposed around Astrey, and in the stream sections show a passage from the sandstones and marls into the Red Marl. This was noticed by Howell years ago. To the south at

Warton thick sandstones, which have been quarried for building, dip at 9 degrees, being influenced by the boundary fault, but eastward they are more horizontal. The same thick building stones crop out at Newton Regis and Seckington.

At Dordon Hall Trias Sandstones and Coal-measures are seen on either side of the road faulted into this position by the Polesworth fault, which here strikes north. The Red Marl in this district exhibits little or no variation except where sandstone features are developed. A skerry band near the top is discernible, but is seldom exposed and cannot be traced over any distance. Another not far from the base of the waterstones in this region makes a feature where it thickens out into a more massive sandstone. There are some thin gypsum bands towards the base, but they are of no importance. It is only in the valleys that the Red Marl affords any exposures of any extent apart from the hard bands. There are no brickyards affording sections that throw any light on the stratigraphy, so that it is necessary to rely on borings for a knowledge of the deeper geology of this region.

The sandstones that are so massive about Orton-on-the-Hill thin out towards Appleby Parva, where they are seen to the south, and at No Man's Heath they thicken and are divisible into two bands showing marked flexures. These are continuous southward between Astrey and Norton, where a third band comes on above these which thickens to a broad outcrop with a sinuous contour at Little Orton. Just south of this a fourth band crops out below these three. Between Twycross and Orton-on-the-Hill there are five or six bands which thicken considerably and run in a north and south direction in a more or less parallel manner with similar undulatory contours. The sandstones give a marked character to the scenery, the hard and soft bands (of marl) alternating and forming diversified country. They can be traced southward to Sheepy Magna, where they are cut off by the valley of the River Sence, and are not traceable south of this point. But, as remarked by Howell, "there are numerous thin bands of greenish-white micaceous sandstone (called 'skerries' by the miners) throughout the whole of the marl, and it is probable that the beds at Orton Hill are formed by a local thickening of some of these bands, for they lie at a much lower horizon than those mentioned by Sir Roderick Murchison and Mr. Strickland between Henley-in-Arden and Warwick, presently to be described." These sandstones are feebly represented around Shackerstone and Carlton Bridge (see district 3). They are ripple-marked and have been used in situ as threshing-floors. They were said by Coleman to be only 1 yard thick, but, as remarked by Howell, they reach a thickness of 20–30 feet, and are probably represented in the boring at Lindley Hall (*supra*) by a bed of sandstone near the base 18 feet thick which is red in colour. That at Orton is mainly white, which is probably due to weathering.

In the northern part there are numerous beds of white sandstone in the Red Marl, as proved in borings at Snibstone (No. 1) (510 O.D.), where 166 ft. 7 in. of Red Marl overlies 21 ft. 9 in. of dolerite, with 7 feet white sandstone at 79 ft. 6 in., 3 ft. 6 in. at 104 ft. 6 in., 5 feet

at 110 ft. 6 in., 3 feet at 143 ft. 10 in., 2 feet at 156 ft. 7 in., 4 ft. 2 in. at 161 ft. 5 in. In the boring at No. 2 (510 O.D.) 179 feet of Red Marl overlies the Coal-measures with twelve bands of white and brown sandstone from 3 to 11 feet thick and a white conglomerate 1 ft. 6 in. at 159 feet. At Hugglescote 201 ft. 9 in. Red Marl overlies Coal-measures (at 514 O.D.), and there are five beds of brown or white sandstone from 2 to 12 feet thick. Probably, as these beds are not far from the base of the Red Marl, and Lower Keuper Sandstone underlies them in borings to the east with a basal conglomerate, they represent some of the beds seen at the surface at Orton.

To the south, at Market Bosworth, several borings have been made which give some idea of the thickness of the Red Marl and the extent of the Lower Keuper sandstones and marls in this district. At the Bosworth Wharf boring at the railway station (300 O.D.) the section was Drift 10 feet, Keuper Marl 332 feet, Lower Keuper Sandstone 219 feet, Bunter 178 feet, Breccia 10 feet, overlying Cambrian rocks. In the Red Marl there are no sandstone beds of importance, but in the Lower Keuper Sandstone two beds, each 18 feet thick, represent those seen at the surface on the west. In the Kingshill Spinney boring (300 O.D.) there was 126 feet Drift, 246 feet Keuper Marl, 322 feet of Keuper Sandstone, 124 feet Bunter, and a Breccia 30 feet overlying 206 feet Stockingford Shales. The above is from Mr. Plant's MSS. He regarded the 206 feet Stockingford Shales as Carboniferous rocks. Professor H. Browne considered the whole 1,030 feet as Trias. The lower part, he says, was in coarse sandstone with rounded pebbles, evidently Bunter conglomerates, and he considers this fixes their easterly limit in this region. To the north-east of Charnwood Forest they are developed much further east, however. It is probable the thickness assigned to the Lower Keuper is excessive and that half of this may be Bunter Sandstone.

The boring at Cow Pasture, 800 yards north-east of the church (380 O.D.), as given by Mr. Plant and corrected by Professor Brown, is as follows:—

	feet.
Boulder-clay	40
Red Marl and sandstone	299
Bunter [?] Sandstone	39
Breccia	50
Stockingford Shales	119
	547

At 500 feet an igneous rock was met with. The Trias here has thinned out considerably as it approaches the pre-Carboniferous ridge. At Lindley Hall in the extreme south 660 feet of Trias were pierced, some of which, at the base, were probably Lower Keuper Sandstone.

Since the Orton Sandstone forms so distinct a feature locally and is probably to be correlated with the Castle Donington, Kegworth, and Diseworth Beds in the Red Marl, we propose to give them this name, *Orton-on-the-Hill Sandstone Group*, to distinguish them from those at a higher horizon in the Red Marl at Dane Hills, Croft, Narborough, and elsewhere.

(3) *Hinckley and Croft District.*

The best boundary for this uniform tract of Red Marl, with intrusive knolls of syenite in the south-east, is on the west the Shackerstone line, on the south the Watling Street, on the east the Leicester and Rugby branch of the Midland Railway, and its Burton and Leicester branch on the north, with the West Bridge line. It is in this area in the south that we have indications of the Upper Keuper Sandstone lying near the top of the series. In the extreme west south of Nailstone a wide tract of Boulder-clay obscures the Red Marl entirely, except just round Market Bosworth, to which reference has already been made. The eastern side is also much obscured by drift, but numerous streams have cut through this mantle and exposed the Red Marl in a series of ramifying branches north of the Soar Valley. To the south the River Soar has spread a wide tract of alluvium over the excavated Trias, and elsewhere it is covered by drift right up to the Liassic outcrop, and covers the Rhætics in the north-east corner except where quarrying has, as at the fine section at Glen Parva, exposed them. Owing to the existence of outliers of syenite, which rise up in dome-like masses forming isolated knolls, a good many sections in the Trias are accessible, and the relation of the Red Marl to the pre-Carboniferous floor can be studied with great advantage. Reference to the paper by Mr. Harrison on this subject will facilitate any observations on this head, and it is not intended to deal with this aspect here in any great detail. Though there are no exposures of Lower Keuper Sandstone in this district, borings for coal south of the Burton line have encountered a variable thickness of this member. At the South Leicestershire Colliery, just south of Bardon Hill, 178 ft. 11 in. of Red Marl and Sandstone were pierced with five beds of whitish sandstone varying from 2 to 9 feet in thickness. At No. 2 the Trias was 181 ft. 2 in. thick, and overlaid dolerite, as at Whitwick. At the Ibstock Old Pit (470 O.D.) 124 ft. 6 in. Red Marl and sandstones overlie a conglomerate or Crossil bed 2 feet thick. Five beds of sandstone 3 to 9 feet thick were encountered, some of this belonging to the Lower Keuper. At Ellistown Colliery (560 O.D.) there is a bed of skerry 6 feet thick at 205 feet, marl and skerry 10 feet at 245 ft. 9 in., which is probably the same as a bed 12 feet thick at Nailstone. This is perhaps equivalent to a skerry outcropping in District (4) at Botcheston, and in the Lindridge borings.

In the brickyard at Bagworth Station six green marly bands and a skerry 1 foot thick are exposed. Ripple-marks north 20 degrees west are frequent in the skerries, and are exceptionally deep. Pseudomorphs of salt crystals are frequent. As at Sileby and Bardon, vertical streaks of Green Marl, deltoid in shape, depend from below the Green Marl bands, chiefly from the top band, but here and there from others, but this does not occur in the Red Marl. In the Bagworth Colliery section (533 O.D.) 315 feet marls, skerries, and sandstone overlie a conglomerate 1 ft. 6 in. At 203 feet stone 20 ft. 6 in. was met with. This probably represents the Orton-on-the-Hill Sandstone. In the Bagworth new sinking (533 O.D.) 299 ft. 4 in. of Red Marl, sandstone, gypsum, and skerries overlie a conglomerate 2 feet thick.

There is a strong white sandstone 9 feet thick at 235 feet, and a stony sandstone 3 feet thick at 282 ft. 5 in. At Nailstone (500 O.D.) there were 180 feet Red Marls and skerries, light-blue sandstone rock 12 feet, marls and skerries 60 feet, conglomerate 5 feet thick, the lower part Lower Keuper.

The sandstone which is seen at the surface at Shackerstone and Carlton Bridge may represent the Orton-on-the-Hill Sandstone.

A boring at Newbold Verdon (400 O.D.) shows—

	ft.	in.
Sand and marl	57	0
Red Marl and gypsum	216	0
Grey rock, probably skerry	2	6
Marl and gypsum	21	6
Marl and sand	26	0
Grey rock	4	3
Pink and purple marl	15	3
Hard grey grozzly bed	17	6
Soft parting	0	6
Hard rock with red and blue partings	7	9
	368	3

The lowest 100 feet is probably in the Lower Keuper here.

In a boring at Stockshouse Farm, Peckleton (400 O.D.), 372 feet Keuper Marl and Sandstone overlaid 88 feet of Coal-measures, 12 feet Millstone Grit, 27 ft. 6 in. Carboniferous Limestone, and 37 ft. 6 in. of a rock resembling Warwickshire camptonite or diabase.

De Rance gives a section at Desford of 213 feet marl and 140 feet waterstones. At Desford No. 1 (400 O.D.) 256 ft. 3 in. of Red Marl, gypsum, sandstone, and skerries overlaid a conglomerate 6 feet thick. Three beds of sandstone 2–15 feet thick were encountered, the last (Lower Keuper) at 239 ft. 3 in.

Several borings were made at Lindridge, near Desford, nearer Bagworth. At No. 1 at 325 O.D., close to the lodge near Lindridge Hall, the section was given as—

	feet.
Drift	2
Upper Keuper Sandstone	20
Red Marl and gypsum	44
Lower Keuper Sandstone	204
Slaty Rocks, Red Marls, dipping at 70	114
	384

De Rance gives this as at 400 O.D. and only gives 270 feet. At No. 2 in the south-west corner of a field south of the farm, 1 mile west of No. 1, 277 feet of Keuper Sandstone overlaid 10 ft. 9 in. blue bind, 9 inches stony bind and Coal-measures and five coals 100 feet thick. At the shaft, a quarter of a mile south-west of No. 1 (325 feet), the section was—

	ft.	in.
Upper Gypseous Series	50	2
Grey skerry	6	6
Lower Gypseous	86	10
Grey and red marly sandstone	114	6
Red Marl with limestone	18	0
Coal-measures and four seams	231	0
	507	0

Mr. Plant said he discovered a fine geode containing crystals of selenite in the Lower Keuper Sandstone in the sinking.

Considerations of water-supply necessitated the sinking of a deep well and a boring to the south at Hinckley, which have become rather notorious from the difficulties arising from the different advice tendered and the character of the boring and method adopted. James Plant had charge of the boring, acting as adviser, and his reasons for the choice of the site were somewhat as follows. The ground around Hinckley falls away into the valley on all sides, except on the north-west, where, after a slight depression, half a mile away it rises up to Wykin Hills, and the plateau continues to Crown Hill. The impermanent streams all flow from the town, and are fed at different levels by water from drift beds. He considered waterstones would be reached between 300 and 400 feet, and he stated they were developed most to the south-west, west, and north-west. He referred to a ridge between Hartshill and Charnwood, causing two basins, the western one being the one upon which Hinckley was situated, on its eastern border. As this western basin was deeper the waterstones he argued were thicker. He cited borings at Hawkesbury and Nuneaton, where from the waterstones in twenty-four hours one and a half million and a quarter of a million gallons of water were obtained from depths of 120 and 112 feet respectively. The boring showed in June, 1879, 150 feet Drift, 30 feet Upper Sandstones, 250 feet Red Marl and gypsum, 150 feet waterstones, and he considered the last were penetrated between 390 and 410 feet. Mr. Stooke, who was asked to take the matter in hand, stated at the Local Government Board inquiry, August 12, 1884, that he considered the waterstones were reached at 500 feet. He said the last vein of gypsum was at 526 feet, but he found traces of it down to 726 feet. This boring was 1 mile to south-west of Hinckley. He gives an account of it with a figure and section, in which below the Boulder-clay, 350 feet (down to 500 feet) of new Red Marl with veins of gypsum and beds of sandstone were encountered, then 200 feet of sandstone with nodules of gypsum and beds of marl, and 100 feet of waterstones (down to 800 feet), overlying Permian beds. This last is doubtful. Some confusion has been made here as to the term waterstones. The last 50 feet contained the best water, but it was much too full of mineral matter. It resembles the waters of Leamington, Cheltenham, and Shearsby, in Leicestershire, and its constituents were :—

	Grains in Imperial Gallon.
Chloride of sodium	71·2
Chloride of potassium	traces
Sulphate of soda	238·3
Sulphate of magnesia	8·0
Sulphate of lime	114·4
Carbonate of magnesia	22·3
Silica	1·4
	455·6

This means about sixty grains to the gallon more than the Shearsby water, which has been described as the Cheltenham of Leicestershire, and derives its properties from the Red Marl underlying the Lias Clays.

through which it finds its way to the surface near the inn. The main difference lies in the absence of sulphate of lime in the Shearsby waters, which is accounted for by the strong smell of sulphuretted hydrogen it possesses, caused by the action of iron in the Lias on the gypsum. Mr. Stooke recommended to the Board in place of this site for a boring and supply of water a spot 5 miles from Hinckley, but in his paper refers to one $3\frac{1}{2}$ miles south-west, near the White Stone, Attleborough, where the water was obtained from a well and heading in the waterstones. A section here shows 60 feet Trias, 70 feet Cambrian Shales, half-way between Chilvers Coton and Burton Hastings.

The whole district around Hinckley is much covered by Chalky Boulder-clay as far as Stapleton and Barwell, and no solid rocks outcrop anywhere in the district, so that it is only from borings that information hereabouts is available. The valley being 60 feet below the usual level one would nevertheless expect some beds to crop out. A pit to the west near the Watling Street is in Boulder-clay and Red Marls, but presents nothing of interest. A boring at Elmesthorpe[1] (300 O.D.) showed 68 feet Drift, 120 feet Keuper Marl, 330 feet Keuper Sandstone, 980 feet said by Plant to be Coal-measures, but Professor Brown gives the following reading:—

	ft.	in.
Upper Keuper Marls with gypsum	470	0
Conglomerate or breccia	a few in Cheshire	
Coal-measures	210	5
Stockingford Shales	974	0
	1654	5

He further found an outcrop of the Stockingford Shales on the Leicester and Birmingham line 1,450 yards east of the station, 2 miles north-east of the above boring, the shales being struck in a field on the north side of the line at a depth of 24 feet. He regards the Barrow Hill 'Greenstone' as a Warwickshire diorite, and thinks that the bosses of igneous rock at Sapcote, Enderby, and Croft are intrusions in the shales and associated rocks. It is possible the slate underlying the syenite in Marston's Pit, Enderby, not now visible, is not Swithland Slate but Stockingford Shale, to which it has some resemblance. The occurrence of the shales on the east of the River Soar, though at a great depth in the Crown Hill borings, would seem to favour this view.

These facts show how irregular and varied was the floor upon which the Trias was deposited, and how ancient were the peaks of intrusive rocks which appear here and there through this pre-Carboniferous floor.

At Stony Stanton, in the Bottom Pit, Keuper Marl lies in the hollows of the syenite nearer the church (south side). A rather decomposed mass of syenite forms a dome or saddle, and on either side the Red Marl with green bands fills the troughs abutting against the syenite with the green bands slightly upturned, in contact at the base, and for some distance into the Red Marl angular masses of syenite have been included. The Red Marl is of a densely

[1] This is the Sapcote Freeholt boring.

reddish-brown colour, flaky, and highly ferruginous, giving it a baked appearance. On the north side of the pit a deeper depression in the syenite is filled with chocolate marl with several light bands in a perfectly horizontal manner.

In the pit south of the church Keuper lies on the flat surface of the syenite. In the next pit, close to the Sapcote Road, Keuper Marl lies on the syenite to the north. There is near the base of the Red Marl here a thickish skerry band, which with the grey or green bands above dips at a considerable angle. This may be the equivalent of the Upper Keuper Sandstone at Narborough, Croft, and Enderby.

At Croft the Keuper Marl dips south-east away from the core of syenite at a high angle. There are two marked skerry bands divided by some twenty feet or more of marl. In one green band near the top the colour is splashed and runs down vertically into the Red Marl, as at Bardon Hill, where bands of green marl run down like ribbons vertically into the intervening Red Marl. The skerry grades from a greenish marly rock into a white sandstone 6–10 feet thick, slightly calcareous, with much garnet. At the base there is a breccia of Red Marl with rounded blocks of syenite at some distance, and these present an uneven pitted appearance.

Some of these fragments occur at a considerable height above the line of junction, deposited in bands of green marl. Where the red and green marl touch the line is often rippled and not perfectly even in hand-specimens. The Red Marl presents the baked appearance of beds seen at Star Brick Works, near the concretionary bed. The dip of the beds seems to coincide closely with that of the Red Marl in the bottom quarry, Stony Stanton, where on the north side it rises from the cutting near the Sapcote Road. The manner in which the marls exhibit a radial dip around the syenite bosses was noticed in 1884 by Mr. Harrison. There is here, as elsewhere in the case of these syenite knolls, no intervening Lower Keuper Sandstone, which has its eastern limit defined by a line drawn from near Desford to a point between Hinckley and Elmesthorpe in the south.

The Upper Keuper Sandstone of Croft is not traceable directly between that place and Narborough, but at Newhall Park a thin band strikes north nearly as far as the King's Stand, and forming a wide outcrop between there and Narborough Wood House, swings round in a crescentic manner to the east, dying out north of the latter place. The Red Marl where it is in contact with the igneous rocks is not underlaid by Lower Keuper.

At Enderby, at Marston's Old Quarry in Coal Pit Lane, 10 feet of drift overlies red and green marl, with a thick skerry or sandstone, the equivalent of the Upper Keuper Sandstone, 12–15 feet, lying over tilted syenite, with dome structure. The lowest beds exhibit a clearly defined sharp junction with the marls, which lie on them horizontally, only in one place, over a dome, as at Longcliffe, assuming a slightly undulatory character. Many small thin layers are massed together, and where separated by projections, like the dome, continue uniformly on either side. Harrison describes these sandstones as 2–4 feet thick, and says that they "follow the irregular surface of the granite, and in one place fill up a deep hollow in the

rock so as to be perceptibly curved". He also says that "there are thin courses of sandstone and intervening way boards of green marl in the Red Marl and a thin bed of limy breccia at the base".

Due east of Enderby, at Hafford's Brickyard, near Blaby, a section in Red Marl underlying 6–22 feet of drift, a great part of which is reconstructed Red Marl, shows green marl and skerry, replaced by marl with red and green spots 1 foot thick, and 5–6 feet of Red Marl with 2–3 feet of reticulated gypsum, similar to that at Thurmaston. These beds are similar to those seen in Barrow's Pit (west of the Midland Railway) at Thurmaston, dry, light-red, very sandy, having a burnt appearance, and very flaky and ferruginous. A cutting in the Great Central Railway adjacent to this shows Red Marl 6–10 feet and more compact gypsum 2–3 feet. Elsewhere the Great Central Railway line between Leicester and Lutterworth shows no sections in the marls.

At Braunstone J. Plant stated in 1856 the Upper Keuper Sandstone was exposed in the Braunstone Turnpike Road with a dip of 3 degrees to the east. It has recently been exposed in that direction in shallow excavations at Westcotes and towards Braunstone near the footpath to the village across the fields from Narborough Road, but it is not exposed at present near the main turnpike road. J. Plant in 1858 also said "the strata which form the ridge of land on the west side of the valley running by Enderby, Braunstone, Rowley Fields, and Dane Hills were once connected with similar strata upon the opposite ridge on the east of the same valley". The observations of Browne (1893) and later observers have shown this view to be erroneous. They are absent in the Crown Hill boring. South of the West Bridge line, the Upper Keuper Sandstone is traceable between Braunstone and the Hinckley Road at a number of points and crops out to the south of the latter at several places, being well exposed in the cutting, and sweeps round with a sinuous outcrop in the direction of Narborough Road. Numerous sections to the east show that it extends in the direction of Aylestone, but, as demonstrated by Browne in his exhaustive memoir upon the geology of the Borough of Leicester, it thins out and is ultimately lost.

Selecting one of these where an interesting fauna was observed between Norman Road and Aylestone Mill, on the Aylestone Road, we cannot do better than quote Browne's remarks: "The hill between these two points is upheld by two or more thick beds of hard and compact Upper Keuper Sandstone with intercalations of hard grey marls (skerries), the lowest member being Upper Keuper Red and Grey Marls. South of Norman Road the sandstone has thinned out at 5 feet below the surface, and is, between that road and the preceding section [Granby Road], replaced by pieces of more impure sandstone." The section is 9–25 feet in thickness, and the beds dip to the river at 3 degrees.

The fossils found in the gritty sandstone between the marls were—

Estheria minuta.
Acrodus keuperinus (teeth).
Colobodus frequens (scales) } then new to
Gyrolepis quenstedti (scales) } Britain.
Fish-scales.
Amphibia (bones).

The Red Marl comes on just to the east of this section, at Saffron Lane, where 24 ft. 6 in. to 42 ft. 6 in. of Red Marls, Green Marl, and skerries are exposed, underlying Drift deposits. A few thin bands of fibrous gypsum are present in a thick bed 10–12 feet of nodular Red Marl. Below this comes sandy marl like that at the south end of the Thurmaston pit, which suggests that the skerry in the Thurmaston Pottery is Upper Keuper Sandstone. Below this again the lowest bed is flaky and ferruginous like the bottom bed of Barrow's Pit, Thurmaston (west of the Midland Railway), supporting this correlation.

In an adjacent pit at Knighton Junction brickyard, 36 ft. 6 in. to 51 feet of Red Marls and Green Marl and skerries, with ball gypsum, is exposed in a fine section of the upper beds. Three beds of gypsum are exposed, two over 1 foot thick. The lowest is encrusted with selenite crystals as at Vass's Pit, which is on the same horizon. In places the line of gypsum is replaced by Green Marl, with which it is often associated generally.

Where thick-bedded the Red Marl is similar to that at Gipsy Lane, District (4). The gypsum is often perforated by holes, as at Belgrave. The under surface has an exterior like that produced by raindrops due to some chemical agency. The gypsum is white as a rule, but tinged red in contact with the Red Marl, and is very hard and like alabaster. There is little fibrous gypsum here.

(To be continued in our next Number.)

REVIEWS.

I.—Geological Survey of Ireland.

The Interbasaltic Rocks (Iron-ores and Bauxites) of North-East Ireland.

By G. A. J. Cole, S. B. Wilkinson, Alexr. M'Henry, J. R. Kilroe, H. J. Seymour, C. E. Moss, and W. D. Haigh. Dublin: printed for H.M. Stationery Office by Browne & Nolan, Ltd., 1912. 8vo; pp. vi, 129, with 6 plates, 23 text-illustrations, and 2 coloured maps. Price 3*s*.

FREQUENT mention has been made in memoirs of the Survey to the interbasaltic beds of the North of Ireland, but the recent development of the mineral industry in that area has made a re-survey desirable. The mode of origin of the materials of this conspicuous zone has been a subject of some discussion, and the first chapter in the present memoir is concerned with the progress of observations in this direction. The origin of similar materials in other regions is discussed, and the conclusion arrived at here is that the bright-coloured deposits originated in Eocene or Oligocene times under hot but not arid conditions, similar to those prevailing at present in tropical India or Africa.

In this memoir the area under consideration is divided into four districts—the Northern, East and Mid-Antrim, and the Southern districts. So far as the Northern district is concerned the types of deposits are different in character and mode of occurrence, and do

not all seem to be found together. By far the most important section is that at the Giant's Causeway, where the zone indicates an interbasaltic epoch of long duration, this conclusion being supported by the presence of frequent thick beds of lignite. At numerous localities thin bands of the bright-red bole occur at other horizons, i.e. unconnected with the main interbasaltic zone. It is suggested that these red bands mark periods of rest between the flows, giving time for the decomposition of the successive surfaces of the basalt. In East Antrim the series is represented by two types—red and brown pisolitic iron-ore and lithomarge, or grey bauxitic clays. As noticed in the previous memoir, one type usually occurs to the exclusion of the other. The two sections on Island Magee show that lithomarge is due entirely to the decomposition of the basalt *in situ*, and is not composed of volcanic ash as was formerly thought. Some alterations in the boundary-line between the upper and lower basalt have been necessary in this area, but in the Mid-Antrim district they are not of great importance so far as the area of the mineral deposits is concerned. In the latter district the best iron-ore and bauxite prospects have already been taken up by companies, and details of the various mines are given. Great changes of level occur in the zone, and some may be accounted for by the irregular surface of the lower basalt on which the deposit was formed. There seems to have been a fairly regular drop to the south of about 100 feet to the mile, but of course the original floor of the lignite, iron-ore, and bauxite deposits was probably more or less horizontal.

There is but little to add to existing knowledge of the rocks of Ballypalady and Tardree in the Southern district, but the recent sinking of pits in the Lough Neagh clays has rendered a few new facts available. At Claremont, north-east of Cranford Bay, there is a section of considerable interest, because it suggests that some of the lignite beds in the clays are derived from the interbasaltic zone by denudation. A new explanation for the origin of the remarkable Coagh Conglomerate is brought forward, namely, that it is a much weathered basalt in which the spheroidal structure is highly developed.

Following the description of the outcrop of this zone is a chapter on the plant-remains by Dr. C. E. Moss, who gives a cautious view of the evidence they afford. The Antrim leaf-beds seem to give fairly reliable evidence of climatic conditions, but as regards further evidence Dr. Moss quotes Starkie Gardner's conclusion as still applicable, that "where nothing definite is known, it would be no service to science to add further to the guesses".

Analyses of the ores have been collected from various sources, and are arranged in order as the localities are dealt with in the text. There are two appendices, one by Mr. J. D. Kilroe and the other by Professor G. A. J. Cole. The former discusses the westerly extension of the Upper Basalts, and arrives at the conclusion that the great series to the west of Bann may be to a large extent Upper Basalt. Professor Cole in dealing with the problem of the Lough Neagh clays regards the evidence now available as indicating the post-basaltic age of these clays. If this view be accepted—and the absence of dykes

penetrating them is a strong argument in its favour—then the contained nodules (in which a doubtful *Viviparus* as well as the wood and leaves has been found) must be derived from the disintegration of some interbasaltic zone.

II.—Geological Survey of Great Britain.

Geology of the Country around Winchester and Stockbridge. By H. J. Osborne White, F.G.S. pp. iv, 89, with 12 text-illustrations. 1912. Price 1*s.* 6*d.*

THIS latest, ably written memoir by Mr. Osborne White is concerned with an area of which the greater part is in western Hampshire and the rest in south-east Wiltshire, Stockbridge occupying a central position, while Winchester is in the south-east. The oldest formation exposed is the Lower Chalk, which is seen around Chilcomb in the south-eastern corner. The rest of the succession of the Chalk, to the zone of *Belemnitella mucronata*, occupies the greater part of the area, and Eocene beds extend over part of the southern portion.

Following a general account of each division of the Chalk, full details of the exposures are given, and a long and useful list of fossils is added. It is doubtful whether the zone of '*Schloenbachia*' *varians* comes to the surface, but its existence is proved by two borings; and the outcrop of the Middle Chalk seems to be confined to a small area round Chilcomb. As is well known, the Chalk Rock (called by Mr. White the subzone of *Heteroceras reussianum*) of this area does not present the peculiar lithology that characterizes it in other districts, but its fauna, which comes in a few feet above the base of the *Holaster planus* zone, has been found round Winchester and at Stockbridge. Only the lowest beds of the *Belemnitella mucronata* zone are present, and probably the thickness of these does not exceed 50 feet in the aggregate.

Clays, sands, and pebble-beds make up the Reading Beds as developed south-west of Winchester, and of these the Bottom-bed is the only constant member. The junction of these beds with the Chalk is well seen in the railway section near Kimbridge, described by Sir J. Prestwich. The London Clay is in this area about one-third its thickness at Southampton, but, as the author shows, the northward thinning is only apparent; and the Basement-bed is not so prominent as in the London district. No good exposure of the junction of the London Clay with the Bagshot Sands has been observed. Near the River Test these Lower Bagshot Beds consist chiefly of yellow and buff fine-grained sands with layers of impure pipe-clay and of flint pebbles. Of the Bracklesham Series only the lowest beds are exposed in this area, and these consist of light-coloured sands and glauconitic loams in which drift-wood and remains of marine shells are sometimes found.

Having considered the Cretaceous and Tertiary rocks, the author gives an instructive chapter on the tectonic structure and land forms, and describes the three well-marked anticlines of Stockbridge, Winchester, and Dean Hill. He then considers the superficial deposits—the clay-with-flints, the gravels, and the alluvium. From the

last-named deposit numerous shells have been collected, and a list of fifty-two species, revised by Mr. A. S. Kennard, is given. The last chapter is devoted to economic geology, and deals with soils, road-metals, and building materials; and the hydrology of the district is briefly discussed.

III.—Guide to the Collection of Gemstones in the Museum of Practical Geology. By W. F. P. McLintock, B.Sc. pp. iv + 92, with 43 figures in the text. Printed for His Majesty's Stationery Office. 1912. Price 9*d.* net.

THIS Guide seems to have been overlong in passing through the press. The preface, which was written by the Director of the Geological Survey, is dated March 29, but more than eight months elapsed before the book actually appeared. No doubt the delay was partly caused by Mr. McLintock's transference to Edinburgh. His Majesty's Stationery Office, under whose auspices the book has been printed, cannot be congratulated upon the quality of the paper or the general get-up of the book.

The Guide is intended to serve the twofold purpose of enabling the visitor to find the various gemstones among the non-metallic minerals, with which they are incorporated in the Museum collection, and to identify cut specimens by certain physical characters. It is divided into four chapters, which, on the whole, follow the usual lines: (1) the properties of gemstones, (2) the cutting of gemstones, (3) the imitation, treatment, and artificial formation of gemstones represented in the collection, (4) the description of gemstones. The author of a guide of this kind is faced with the problem how to avoid technicality which would repel the ordinary visitor, and yet to include enough information to make it of real use. On the whole, Mr. McLintock has steered a deft course, and has provided much interesting and readable matter, which is purchasable for a very modest sum.

The specific gravity is the character upon which most reliance is placed for distinguishing one species from another, and various methods for determining it are described. This test unfortunately necessitates the stone being unmounted, and is not very convenient for the retail jeweller or the purchaser of jewellery. The use of an ordinary balance for the purpose might, with advantage, have been described, since few jewellers possess the Westphal balance. The more generally useful test depending on a measurement of the refractive indices and the double refraction is only just alluded to, and the amount of information given is too small to explain the method. In the instrument mentioned on p. 16 the indices are read off directly on a scale, and no calculations are needed as the reader might be led to suppose. The dichroscope and its applicability are more fully dealt with, and in an interesting paragraph the effect of radium emanations upon the coloration of gemstones is discussed. The Museum collection contains some fine specimens, including the gold snuffbox, set with sixteen brilliant-cut diamonds and the large vase of avanturine quartz which were presented to Sir Roderick I. Murchison by the Czar Nicholas I, and the large vase of "Blue John", which is one of the finest examples of this kind of work existing.

In turning over the pages a few points call for notice. The carat weight is used for all gemstones which have any claim to be accounted precious, but for some reason the discussion of it is placed under 'Diamond'. It is not made clear that the Board of Trade takes no responsibility for the carat and possesses no standard of it; it is, indeed, an illegal weight. All the Board has done is to determine the equivalent in milligrams of the carat in use among English jewellers. In the chapter on the cutting of gemstones too much importance is given to the rose-type, which is never found in modern jewellery, and the facets in figs. 11 and 14 are much too steep. It is puzzling to find the pyroxene group (p. 81) placed in the section headed 'Iolite', and we look in vain for enstatite, cut stones of which, from South Africa, are sold as 'green garnet'. Andalusite is probably oftener confused with tourmaline than with alexandrite (p. 67). A good supply of rough peridot is usually on the market, and it can scarcely be said "the peridot now put upon the market is generally believed to be derived from old ornaments and jewellery" (p. 71); the remark is, however, applicable to emeralds. We are sorry to see the faulty spelling 'essonite', without the aspirate, perpetuated. Most kunzite is too lilac in tint to be mistaken for pink topaz (p. 83). 'Adze' is not a word peculiar to the Maoris and need not be italicized (p. 85). The Chairman of the Premier Diamond Mine (Transvaal) Company, after whom the great diamond was named, is Sir T. N. Cullinan (p. 42). 'Burma' and 'Burmah' appear within three lines of one another on p. 75. Some mistake has obviously been made in the drawing of fig. 36. The locality for emerald in New South Wales is Emmaville (p. 63). Few, if any, pyropes have a refractive index as high as 1·8 (p. 74).

Some useful tables and a good index are included at the end of the book.

IV.—The Keuper Marls around Charnwood. By T. O. Bosworth, B.A., B.Sc., F.G.S. Being the results of researches in Leicestershire, 1904–11. pp. 1–129, with 47 illustrations. Leicester: published by the Leicester Literary and Philosophical Society. n.d.

CONSIDERABLE additions have been made during the last decade to the literature of the Trias, a subject to which great attention has been paid by the Leicester Literary and Philosophical Society. In the present work, a beautifully illustrated volume, are embodied the results of Mr. Bosworth's researches in the Keuper Marls of a district that affords exceptional advantages for study. These results have already been published in various scientific journals, but the collection and arrangement of them in the present volume will be of considerable use to future workers.

After giving a short account of the literature of the subject, the author proceeds to a general sketch of the geology of the district, making reference to the different easily distinguishable kinds of rock that are contained in the Charnian mass. In describing the features of the old rock-surface beneath the Keuper Marls the author takes as a typical illustration the quarry in Groby village, and most of the descriptions of the quarries are accompanied by detailed maps.

He then deals with the condition of the buried rocks, owing to the preserving influence of the marl covering, and an interesting chapter is devoted to the breccias, stone bands, and rock fragments contained in the marls. On account of the uncertainty that existed as to the mineral composition of the Keuper Marls, Mr. Bosworth made various experiments, the result of which are given in some detail; and in the discussion of the mineral grains, an interesting comparison is made between the larger grains of the heavy minerals, now rounded and smoothed, and those of a Scottish Carboniferous Sandstone, which are in strong contrast.

The author has for some years been collecting data as to the ripple-marks, and he includes a table of observations in this direction. These ripples were formed under shallow water, and were controlled by the prevalent south-west wind.

The last chapter summarizes the facts very clearly, and some conclusions are drawn as to the mode of deposition of the sediments. Mr. Bosworth offers as his interpretation that the sediments accumulated in an inland basin that was partly dry and partly occupied by comparatively deep standing pools, the climate being arid, and evaporation in excess of precipitation. Streams of fresh water flowed into the desert from the hills south-west, on which was precipitated the moisture of the prevalent wind. At times most of the desert would be dry, and the inflowing water would be spread over the plains and be evaporated before reaching the pools. Under these conditions the grey beds would be deposited, while the red marls accumulated in the standing pools.

There are four short appendices to this volume, and these give details of the sections at Gipsy Lane, Hathen, Sileby, and Whitwick.

V.—Brief Notices.

1. Ore-deposit, Dolores Mine, Mexico.—In *Economic Geology* for August, 1912, Messrs. J. E. Spurr, G. H. Garrey, and Clarence N. Fenner give an interesting study of the metamorphic ore-deposit at the Dolores Mine, situated at the east base of a small mountain range near Matehuala, S.L.P., Mexico. The range, which is of blue Mesozoic limestone, overlain by the shales forming the valleys on both sides, is remarkable for an enormous fault of a vertical displacement of 1,500 metres. There are two areas of intrusive quartz-monzonite, showing evidence of dawning magmatic differentiation in situ, and near them are lime-silicate rocks, the product of metamorphism. The ore-deposition is in the order—copper pyrites and pyrites, mispickel, pyrrhotite and pyrites, blende, galena, the third stage being rich in silver. Mr. Spurr elaborates his theory of ore-deposition, one of the most important features of which is that the metalliferous solutions from which ores are deposited originate in and spring from the zone of igneous rock differentiation, which is in the lower part of the zone of crystallization.

2. In the *American Journal for Science* for October, 1912, Mr. E. T. Allen and Mr. J. L. Crenshaw discuss the various kinds of sulphides of zinc, cadmium, and mercury, and the conditions under which they

are severally formed, and throw considerable light on their production in nature. Alkaline solutions always give rise to blende, never to wurtzite, and the former mineral is also formed under suitable conditions from acid solutions. Only one sulphide of cadmium exists, the differences in colour that have been noticed being due to the relative amounts of light transmitted and reflected. Three forms of sulphide of mercury are known, of which one, cinnabar, is stable, and two (one being the rare mineral metacinnabar) are unstable. The authors conclude by saying, "Enough work has already been done to show that the difference in chemical character between acid and alkaline solutions, therefore, in general between deep-seated and surface solutions, is of vital importance in geochemistry." The microscopic study was made by Dr. H. E. Merwin.

3. Palæolithic Man in Jersey.—In the thirty-seventh Annual Bulletin of the Société Jersiase (1912) there is an account by Mr. J. Sinel of the prehistoric cave-dwelling (Cotte à la Chèvre) east of Grosnez Point, St. Ouen, on the north-western coast of Jersey. Here, according to the author, "we have what may be termed a pure early Mousterian station, free from admixture of other types of relics, and a floor undisturbed by floods or any other agencies." Apart from the Palæolithic implements, there was obtained the jaw of a large species of deer in a decayed condition.

Messrs. E. T. Nicolle and J. Sinel contribute a "Report of the resumed Exploration of 'La Cotte', St. Brelade". Here, again, flint implements, all of Mousterian type, have been found in a cave-dwelling; also remains of *Rhinoceros antiquitatus*, reindeer, ox, and horse, which have been identified by Dr. C. W. Andrews; and, of still greater interest, some teeth of Palæolithic man, described and figured by Dr. A. Keith and Mr. F. H. S. Knowles under the name of *Homo Breladensis*.[1]

REPORTS AND PROCEEDINGS.

Geological Society of London.

January 8, 1913.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "The Geological History of the Malay Peninsula." By John Brooke Scrivenor, M.A., F.G.S., Geologist to the Government of the Federated Malay States.

This paper is an attempt to present briefly and in a connected form all the information bearing on the geological history of the Malay Peninsula that has been gathered during the course of economic work since 1903.

The main points are as follows:—

During the Mesozoic Era earth-movements took place in a part of the crust which is now the site of the Malay Peninsula. These

[1] A brief notice of the discoveries was communicated to the Geological Society by Dr. A. S. Woodward, Quart. Journ. Geol. Soc., vol. lxvii, p. iii, 1911.

movements resulted in the formation of two large anticlinal folds. The folding admitted of the intrusion of two masses of granite, and the intrusion was accompanied by faulting of the rocks in the folds, and by 'magmatic stoping' on a large scale.

The rocks affected by the folding are the Raub Series of calcareous rocks, and the Malayan Gondwana rocks, resting unconformably on the Raub Series, and in many places faulted down against that series.

The palæontological evidence afforded by small collections from the Raub Series cannot be reconciled with the field evidence. No fixed horizon has been discovered in these rocks, which may be either Carboniferous or Permo-Carboniferous. Associated with the Raub Series are volcanic rocks, which are evidence of contemporaneous submarine eruptions. The eruptions continued into later times.

At the base of the Gondwana rocks are glacial deposits that may be referred to the same horizon as the late Palæozoic glacial deposits of Peninsular India, the Salt Range, Australia, and South Africa, but this horizon cannot be defined exactly in the terms of the European sequence. Its presence shows that the Raub Series must be older than the *Productus* beds of the Salt Range, or equivalent to the shales below the boulder-bed in the trans-Indus section of the Salt Range.

The glacial deposits are succeeded by littoral deposits, and far to the east of the glacial deposits a Rhætic horizon has been described in them by Mr. R. B. Newton, and named by him the Myophorian Sandstone. To account for the apparent discrepancy in age between the climatic horizon afforded by the glacial deposits and the Myophorian Sandstone, an hypothesis has been adopted to the effect that the Malayan Gondwana rocks were deposited on the Gondwanaland coastline as it moved slowly eastwards, probably with many checks and oscillations.

The glacial deposits show that this portion of the Gondwanaland coast contained stanniferous granite and also much corundum. This granite is called 'the Palæozoic Granite', as distinguished from 'the Mesozoic Granite'; it is not known in situ. The glacial deposits are therefore part of a Palæozoic tin-field, now being worked at the same time as the stanniferous deposits derived from the Mesozoic Granite.

Denudation has brought to light the two great anticlinal folds and the granite masses upon which they now rest. On the west is the Main Range Anticline, on the east the Benom Anticline. The eastern limb of the former and the western limb of the latter meet in the Main Range Foothills. The eastern limb of the Benom Anticline is formed by the main Gondwana outcrop, which includes the highest peak in the Peninsula (Gunong Tahan, altitude 7,188 feet). It is believed that this main Gondwana outcrop is continued through the Peninsula to Singapore, and on to Banka and Billiton, where it may turn so as to enter Western Borneo, forming an inner arc roughly parallel with the outer volcanic arc of the Malay Archipelago and the Philippines.

The igneous rocks of the Benom Anticline are less acid than those of the Main Range Anticline, and there is a corresponding

difference in mineral products. The area of the Benom Anticline coincides with the 'gold-belt' of the Peninsula. The products of the Main Range Anticline are tin and wolfram.

Tertiary Coal-measures, unconformable on the Gondwana rocks, are known in Selangor. Their exact age cannot be determined, since the flora resembles the existing jungle flora; and the same may be said of floras in Borneo Coal-measures that are believed to date back to the Eocene Period. An arrangement based on the percentage of moisture in the coal, however, points to the possibility of their being Miocene.

Evidence has been found in the Peninsula supplementing the biological evidence described by Dr. A. R. Wallace of changes in the Archipelago in Tertiary times. When the land-connexion that allowed the migration of the fauna of the Archipelago from the north was destroyed by submergence, the subsidence continued until the Peninsula became an island or group of islands. Subsidence then gave place to elevation, which restored the Peninsula and is continuing at the present day.

Interesting recent deposits are deposits of lignite in 'cups' formed by solution in the limestone of the Raub Series, and torrential deposits made up of 'core-boulders' derived from weathered granite.

2. "On a Mass of Anhydrite in the Magnesian Limestone at Hartlepool." By Charles Taylor Trechmann, B.Sc. (Communicated by Professor E. J. Garwood, M.A., V.P.G.S.)

The harbour of Hartlepool owes its existence to the erosion of a mass of anhydrite of great thickness, proved by boring and other evidence to exist in close proximity to the Upper Magnesian Limestone upon which the towns of Hartlepool and West Hartlepool are built.

The anhydrite is shown to be included in, and to represent the time-equivalent of part of, the Middle and the greater part of the Upper Limestones. The contrary view, that the anhydrite belongs to the overlying red beds here faulted down, is shown to be erroneous.

The former presence of sulphates in the Magnesian Limestone is discussed. This formation, wherever protected by overlying comparatively impervious beds, proves to be more or less gypsiferous throughout its thickness. Evidence is brought to show that very large quantities of anhydrite were originally deposited with the Magnesian Limestone, the subsequent hydration and removal of which is chiefly responsible for the collapse, degradation, brecciation, and other alterations that are such obvious features of the formation in its present condition.

The distribution of organisms in the Magnesian Limestone was largely influenced by the quantity of sulphates present in the surrounding water. The Shell Limestone is shown to be a chain of reef-knolls, in the building up of which a limited number of forms take part, probably induced by current action in the Permian sea and lying more or less parallel with the old Permian shore-line. The increasingly unfavourable conditions prevailing towards the top of the Shell Limestone bring about a dwarfing and gradual extinction of the typical Shell Limestone fauna.

The curious distribution and present position of the Upper Magnesian Limestones in Durham is noticed, and an explanation offered.

The Permian succession is shown to be more complete in the southern than in the northern area of the county.

Various sections in the Upper and Upper Middle Limestones in the Hartlepool area are described, among them the recent sinking for Blackhall Colliery, where all the series were pierced, including the full thickness of the Shell Limestone.

CORRESPONDENCE.

SEA-WATER AND CRITICAL TEMPERATURES.

Sir,—I have been very much interested in Professor Bonney's contribution to "The People's Books" in his *Structure of the Earth*. From repeated inquiries for such a clear and lucid introduction to geology, I know by experience how much such a work has been wanted.

It is, of course, a great pleasure to myself to note the stress that Professor Bonney lays on Professor Arrhenius' view of the penetration of the rocks by sea-water, both under pressure and by means of capillary attraction; but, in justice to the fathers of geological science, I should like to point out that Sir Henry de la Beche taught the doctrine of the entrance of sea-water into the earth's crust by pressure; that Professor Daubrée proved by experiment the power of capillary attraction to overcome the opposing resistance of steam as published in 1879 in his *Géologie Expérimentale*, ch. iii; and that Professor Judd, in 1881, endorsed and popularized this doctrine in his *Volcanoes, what they are and what they teach*, pp. 358, 359, besides pointing out the importance of the critical temperatures of liquids in the same work, p. 63.

Daubrée supposed that granite would ordinarily be very impermeable to water, and suggested the possible access of water through dykes of porous rocks ("par des injections de roches éruptives," loc. cit., p. 242). I, however, in 1890 showed that "under extreme changes of temperature granite cracks throughout", and that "a minutely cracked granite would suck in salt water like a sponge, either under pressure or by *capillary* attraction".[1] The experiment is simple, viz., to heat a piece of granite in an ordinary fire, and to soak it when cool in coloured water. I respectfully submit that the important question of the penetration of rocks by water was, long before 1880, promoted from the rank of a mere 'view', even of so distinguished a chemist as is Professor Arrhenius.

I have often wondered why the convincing experimental demonstrations of Professor Daubrée were so completely ignored in the closing decades of the last century, and venture to suggest the following as a possible explanation. In mid-Victorian times all educated people were expected to know something of the French language, but they rarely knew German. About 1870 German

[1] Rep. Brit. Assoc. 1890, p. 815.

became the language desirable for scientists, and French was allowed to lapse. Being a pre-Darwinian myself I can read Daubrée with pleasure, but German is to me a sealed book scientifically.

The French writers on physical geology, such as Daubrée, Delesse, Fouqué, and Lévy, appeal greatly to the followers of the old-fashioned English methods of experiment and demonstration, with the avoidance of 'views', and when possible of 'theories'.

As readers of the GEOLOGICAL MAGAZINE are, perhaps, too well aware, I pressed the two subjects of the permeation of rocks by fluids and of the critical temperature of liquids on them at every possible opportunity between the years 1892 and 1903, having in the year 1892 entirely renounced further original work, as being quite futile so long as the main principles were denied, and retiring entirely in 1904 when tacit opposition became too pronounced. I remain more and more convinced that since the waters first covered the earth no single agent has been more active in the processes of rock-metamorphism than the oceanic waters, charged as they are with soda, potash, magnesia, and lime.

A. R. HUNT.

TORQUAY.
December 31, 1912.

OBITUARY.

ELLEN SOPHIA WOODWARD.

BORN AUGUST 7, 1836. DIED JANUARY 10, 1913.

THE beloved wife of the Editor of this journal, and the compiler of a *Forty Years Index to the Geological Magazine, 1864–1903* (Dulau & Co.), passed peacefully away, after fifty-five years of happy married life, on January 10, 1913, at 13 Arundel Gardens, Notting Hill, W.

She took a keen and active interest in science, and greatly assisted Dr. Woodward in his geological and literary work, both in the British Museum and at home. She also accompanied him, for many years, to the meetings of the British Association and on visits to the Continent.

MISCELLANEOUS.

RETIREMENT OF MR. CLEMENT REID, F.R.S., F.L.S., of the Geological Survey of England and Wales.

Mr. Clement Reid, District Geologist on the Geological Survey, retired from the public service on January 6, 1913. He joined the staff of the Survey in 1874, under Sir A. C. Ramsay, and has been actively engaged in field-work for more than thirty-eight years.

Mr. Clement Reid is distinguished for his knowledge of the Tertiary floras, and is the author of many papers and Survey memoirs, including the *Origin of the British Flora*, 1899. He was awarded the "Bigsby Medal" in 1897, and was elected a Fellow of the Royal Society in 1899.